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The Future of British Industry.

Sir Alfred Bateman's Report.

We have so frequently had occasion to criticise the doings (or the absence of them) of the Commercial Intelligence Department of the Board of Trade, that it is with a refreshing sense of novelty that we extend some words of approval to the short, though laboriously executed work on British Trade and Industry, issued last month on behalf of his Department by Sir Alfred Bateman.

The "Memorandum" on the "Comparative Statistics of Population, Industry and Commerce in the United Kingdom and Some Leading Foreign Countries," though not an especially valuable achievement, is decidedly an interesting survey of contemporary circumstances from an economical standpoint. It contains no facts not already generally known, and the conclusions expressed by the author have long since settled in the minds of most intelligent business men. Still, notwithstanding the absence of any new points of view, Sir Alfred Bateman's Memorandum forms a brilliant example of that expert marshalling of statistical detail in which, it must be acknowledged, our Board of Trade have yet to discover their masters. There are few, if any, unnecessary figures, and the excision apparent in it of that superfluous detail with which this class of statistical literature is too often overburdened, is not the least merit of a work, the general excellence of which has aroused an applause all the more enthusiastic, perhaps, because the opportunities for this sort of demonstration in relation to the performances of the Board of Trade are so limited as to be altogether exceptional.

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The chief object of Sir Alfred Bateman's report is to show the rate and degree of progress made by the principal manufacturing Powers compared with that of Great Britain; their relative position as to home trade and neutral markets; and how far, if at all, British trade has been encroached upon by the growing rivalry of its competitors. The work necessary to such an undertaking is far more onerous than would be inferred from the results embodied in the publication before us. It is certain that an enormous amount of labour has been condensed in what Sir Alfred Bateman modestly designates as a "Memorandum," and he deserves great credit for not merely the lucidity with which he has treated a subject which naturally tends to undue elaboration, but for the suppression of a vast body of matter which, in the hands of another author, might have been employed to give a ponderous effect to his disquisition at the expense of that directness and simplicity which are a gratifying feature in Sir Alfred Bateman's work.

The position on which Sir Alfred Bateman takes his stand for a survey of the world's commerce is not a new one in this connection. But it has never before afforded such a clear and comprehensive view as that which the author presents to his readers on this occasion. The prospect he discloses may not be a comforting one as it affects our pride of race; but at

any rate the consolation is united to it that if the triumphant march of British industry is at length to slacken, and even in the course of a few short years to altogether cease, it is owing to no degeneration in the national character, nor to decadence in the aggressive vigour of our race.

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Sir Alfred Bateman has elected to consider the subject on the proposition that the basic foundation of the trade and industry of a nation is fixed upon the proportion of its industrial population.

The Foundation of Industry.

That proposition we think may be accepted without demur, though it entails a series of postulates which, so far as they regard the Mother Country, form, to those who look forward to a continuance of the manufacturing ascendancy which has distinguished Great Britain during so many years, a subject of melancholy contemplation. Sir Alfred Bateman, in fine, has arrived at the conclusion that the zenith of England's relative manufacturing and commercial power has been reached; and that, although an era of prosperity still lies before us, we are bound in the natural sequence of events to become eclipsed in course of time, in manufacturing productivity, by at least one other Power. He shows, by evidence which it would be difficult to impeach, that a steady and irresistible process of metamorphosis is taking place in the populations of Germany, the United States, and in a smaller degree that of France, in which these agricultural populations are gradually merging into those devoted to manufactures. This fact is strikingly shown in a series of numerical tables, where the growth of the urban populations of the respective countries named is shown throughout a series of years. In respect to this—and the matter is sufficiently important for the passage to be quoted at length—the author says:—

"In absolute numbers the increase in the town population, both in Germany and the United States, is beginning to be greater than can be the case in the United Kingdom. In Germany the increase in thirty years is 15¾ millions, and this exceeds by 5¾ millions the total increase of the population of the United Kingdom in the interval, so that, even allowing for a transfer from rural to urban in the United Kingdom, the absolute increase of the numbers of the urban, and we may reasonably assume of the commercial, manufacturing, and industrial population in Germany, has probably been somewhat greater than in the United Kingdom. As to the United States, there can hardly be any question. The increase of 17 millions in the town population of the United States between 1870 and 1900 exceeds by 7 millions the total increase of the population of the United Kingdom in the same period, and the transfer from rural to urban with us cannot have been anything like that figure. In other words, both Germany and the United States have attained to the position of increasing their non-agricultural population more quickly than the United Kingdom; and looking at the larger mass of the population in both countries and their rapid rate of growth, there seems no doubt that unless something happens, which does not seem probable, to make people go back to the land, both Germany and the United States will in a short time possess a larger non-agricultural population than we have, and one which will increase more rapidly in numbers."

Armies of Workers.

These facts, which are indisputable, afford premises which draw Sir Alfred Bateman to the conclusion that English manufacturing and industrial predominance, and even pre-eminence, is not what it was when the non-agricultural populations of every other country in the world were smaller than our own. We are now being confronted with armies of industrial workers, growing rapidly every year in volume, while our own, if not absolutely stationary, is not increasing at nearly so great a rate as those of competing nations. In this respect, the enormous population and gigantic resources of the

United States are only, so to speak, on the margin of a vast expanse of industrial development, which, if not a menace to our prosperity, appears bound, in time, to deprive this country of its manufacturing predominance, and to render the United States the chief industrial power in the world.

An interesting circumstance, which will afford the British reader more gratification, is found in the comparison instituted by Sir Alfred Bateman between the great industrial Powers on the basis of population units. This aspect of the survey is a remarkable one. The figures compiled show that the exports, for instance, of England, France, Germany, and the United States are, per head of population, of the following values:—France, £3 14*s.* 8*d.*; Germany, £3 7*s.* 2*d.*; United States, £2 18*s.* 4*d.*; while that of Great Britain averages to no less than £5 19*s.* 5*d.* per unit of population. The same stands good, in even greater contrast, with respect to the imports, which in England are £9 17*s.* 2*d.*; France, £4 4*s.* 9*d.*; Germany, £4 6*s.* 10*d.*; whilst the United States show the relatively insignificant amount of £1 19*s.* 11*d.* per head of population. It is only just to state, however, that these countries are rapidly advancing, and that their rate of increase is far greater than our own. That is to say, while our own rate has remained practically stationary, the increase in exports per unit of France during the past few years has been at the rate of 12·3; that of Germany, 36·6; while that of America has leaped to 153·9.

The Expansion of Manufactures.

The remarkable fact, however, remains, that this extraordinary expansion of manufactures on the part of our rivals has been effected without any appreciable encroachment upon British Home, Foreign or Colonial trade. It is true we have lost ground slightly in our export trade with Argentina, Chili, Uruguay and China, but the volume of our business infringed upon in these instances has been more than compensated by advances in other directions. As Sir Alfred Bateman says:—

> "The figures . . . show that we have not stood still. They show that we have progressed, although Germany and the United States have progressed more rapidly; but they do not show any displacement of export trade of the United Kingdom in the period in question (five years) by any one of the principal competitors."

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The conclusions arrived at by Sir Alfred Bateman on the evidence he has adduced are important; and it is difficult to regard them in any other light than undeniable. They are sufficiently important to be quoted in full, for that condensation everywhere observable in this Memorandum is sufficiently evident in his summary.

> "The increase of population in Germany and the United States has recently been greater than the increase in the United Kingdom, and those countries have rapidly developed manufacturing and industrial power. We are still ahead of either country in our power of manufacture for export, but beginning from a lower level, each country is travelling upwards more rapidly than we are who occupy a higher eminence. If peace is maintained, both Germany and the United States are certain to increase their rate of upward movement. Their competition with us in neutral markets, and even in our home markets, will probably, unless we ourselves are active, become increasingly serious. Every year will add to their acquired capital and skill, and they will have larger and larger additions to their population to draw upon. It is necessary, therefore, more than ever that the change of conditions should be recognised, and we can scarcely expect to maintain our past undoubted pre-eminence, at any rate without strenuous effort and careful and energetic improvement in method. The problem how best this can be done is of vital interest to all classes of the industrial and commercial community alike, though the assistance which the State can give in the matter must necessarily be of a limited character."

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Having quoted Sir Alfred Bateman's carefully expressed views on the world's industrial situation, we may fittingly conclude with some observations of our own. We note in this work a series of figures, referring to a subject whose adequate treatment during the recent Colonial Conference would have been most valuable and appropriate. During the whole of the discussion on preferential tariffs between the mother country and her dependencies, the proposed institution of which had no other object than that of the diversion of the trade being carried on by foreign countries with the British Colonies to the United Kingdom, no information respecting the approximate value of the trade which we are so anxious to secure has been generally accessible to the public.

Imperfect Figures.

Two years ago a return was procured with infinite trouble from the Commercial Intelligence Department of the Board of Trade on this subject on behalf of FEILDEN'S MAGAZINE, but it was regarded as too imperfect and unreliable to be dealt with upon an authoritative basis. To our surprise we have found a nebulous approach to these figures given in the book before us. It is true that even in this case their specific importance does not appear to be realised, for they form merely a portion of a larger and more general arrangement of statistical tables, and are not quoted with any relation to the purport for which we are now employing them. As they stand their expression is sufficiently irritating, and as an example of the characteristic business ineptitude of the Board of Trade officials leaves little to be desired.

We find that the "average total imports" into British possessions for 1898—1900, as given in detail amounts, sum up a gross total of £268,000,000. We take this to be a yearly average, though the compiler of the figures has adopted a position of judicious ambiguity on this point, whilst the English proportion of manufactures to the Colonies is expressed in percentages on each total. The only way of arriving at an estimate of the foreign trade with the oversea markets under the British flag is therefore to work out these percentages, and this we have done with the following results, which we may be pardoned for putting forward without accepting any responsibility for their correctness other than that derived from their source.

The average yearly total of imports of the British Dependencies during the term stated are set out at £268,000,000, of which the proportion of the mother country shows a gross average of 41 per cent. The remainder is presumably divided between foreign countries and inter-colonial trade, the percentages taken by Germany working out at 22·1, France 7·7, and the United States at 15·4 of the total; which percentages, on the figures given, represent a volume of foreign trade with our Colonies and Dependencies of some £160,000,000 a year going away from this country to its competitors.

Lost Colonial Trade.

These figures, however imperfect they may be in themselves, and useless for any other than the most general interpretation, convey a concrete idea of what there is to be gained by the manufacturers of this country from the markets of our own kith and kin beyond the seas. The question of preferential trade with the British Colonies has been the object of great derision from so-called economists, fostered and brought up on the doctrines of Cobden and his coadjutors, and there is unfortunately little doubt that any effort toward a practical advance on this has been to a great extent thwarted for the time by the exertions of those who appear willingly disposed to sacrifice the interests of the country for a pet theory. But the period must come when statesmen and men of business will join forces and show that it is not beyond the capacity of modern men of affairs to direct this wandering stream of alien trade into the broad river of commerce which constitutes the great bond of a homogeneous Empire.

The Colonial Conference.

WHEN reviewing the events of the past month, the thought will occur to many that compensation has not been altogether wanting for a preceding period of national sorrow and anxiety. In the hour of danger all classes of the community, and all members of the family of States forming the British Empire, were drawn closer together by a common chord of sympathy, and the recent time of celebration and festivity has also been a time of thanksgiving for the whole British race. If the Coronation of His Majesty was shorn in some measure of its splendour by reason of the absence of foreign representatives, it undoubtedly gained in significance owing to its markedly Imperial character. Our brothers from Dominions beyond the Seas, and from the Indian Empire, have been longer in our midst, and the bonds connecting the scattered States of the Empire have been further strengthened.

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The month that is now past also witnessed the conclusion of the first conference of Colonial Premiers, a gathering only rendered possible by the steadfast affection of the Colonies for the Mother Country, and, we may add, by the sympathetic and wise statesmanship of the Colonial Secretary. We are happy to know that the Conference is not to be looked upon as an isolated meeting, but that it is to be followed by others at stated periods, when the individual needs of different States and the collective welfare of the Empire will be more fully discussed. It would be unreasonable to expect any startling development as an immediate result of such a meeting as that held last month, for it must be remembered that those participating were merely representing independent legislatures, and were unable to do more than to suggest and to approve in principle the proposals to be submitted for consideration thereafter. Even if nothing at all tangible had been the outcome, the very inauguration of such a conference would constitute an unprecedented event in the history of the world, and a striking testimony to the sure and just foundations of British rule.

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But we are pleased to announce that results have been attained which are clearly satisfactory from an Imperial point of view, as a general agreement has been arrived at, marking a decisive step towards the organic unity of the Empire in matters of defence and fiscal policy. Of course, we must not lose sight of the fact that where numerous self-governing States are concerned, the establishment of a rigidly uniform scheme would be out of the question; for each State must consider matters from its own standpoint, and with due regard to special local conditions. It is equally important that nothing should be done by the Imperial Government that might have the appearance of attempting to substitute a chain of duty for the bond of spontaneous patriotism that now connects the Colonies to the old country; and it is an essential condition that the consolidation of the Empire, now within measurable distance, shall be effected without interfering with the full autonomy of its constituent parts.

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With regard to the maintenance of the Imperial Navy, no question of the kind arises, and the universal desire on the part of Colonial Governments to make increased contributions towards its cost affords satisfactory evidence of the Imperial spirit. The amounts proposed to be set apart are more valuable as tokens of goodwill than financially, and they will tend to encourage in the Colonies a healthy feeling of proprietorship. The arrangement that Colonists shall be allowed to participate in the provision of officers and sailors will also create additional interest in the Navy. The discussions on the subject of military forces serve to indicate the unsuitability of uniform regulations. Some of the Colonies are ready to set apart a certain proportion of their local

troops as reserves to be ready at the call of the Imperial Government; while others think it sufficient that their forces should be maintained in a state of efficiency, it being left to the loyalty of the people to assist the Government in an emergency, as they did in the case of the South African War. Individual preferences of this kind must certainly be respected, especially in the early days of Imperial unity.

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One kindred subject discussed at the Conference was that of Navy and Army contracts. The Colonial Premiers justly urged that the Imperial Government should give preferential consideration to Colonial contractors in connection with the supply of products for the use of the Navy and Army. Dissatisfaction is not entirely unknown in this country with the methods pursued by some Government departments, and it would not be at all surprising if a similar feeling were experienced in the Colonies. Evidence was produced on behalf of the Government showing that the Colonies had already been specially considered, but this is a somewhat diplomatic phrase which does not necessarily imply preferential treatment. Very likely "special consideration" is always given to the tenders of British locomotive builders and other engineers, but the operation by no means prevents the issue of extensive orders to foreign firms, and sometimes on more favourable terms than those accorded to manufacturers at home. Our own authorities might advantageously follow the example set by foreign Governments in the encouragement of home industries, even at the sacrifice of fractional differences of cost. We sincerely trust that the Colonies will receive the most liberal consideration in the future, for nothing will tend more to alienate sympathy than neglect to encourage the staple industries on which the prosperity of those countries so much depends.

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So far as the fiscal arrangements of the Empire are concerned, we may say that it would be an impossible task to inaugurate at short notice a general system of free trade, as some of our contemporaries seem to think can be done. Colonial Governments at present favour protection, and rely upon duties for the provision of revenue. Consequently the remission of duties, wholly or in part, must involve readjustment of taxation, which is a matter requiring careful consideration, and one upon which the peoples affected must certainly be consulted. Apart from this aspect of the question, it seems only equitable that some reciprocal advantages should be offered by the home country in return for preferential tariffs, and for the moment it is not evident that anything of the sort is proposed. This negative position renders still more praiseworthy the unanimous disposition of the Colonial Premiers to follow the splendid example set by the Dominion of Canada. Again, it will be out of the question to force any action of this nature into a uniform groove, although there is a fixed and definite understanding that each State will do everything possible to promote commercial relations within the Empire. In this work the home Government should be able to help materially, for while we have practically no duties available for reduction in favour of Colonial produce, it should be possible to extend the principle, already adopted in connection with the West Indies, and so to enable food and other products for the home country to be imported on such favourable terms that supplies may be drawn from within the Empire rather than from foreign countries.

Important as the preliminary results of the Conference undoubtedly are, the clear recognition made of the need for Imperial unity is still more important. The inauguration of the Conference and the arrangement for periodical meetings of the same character clearly foreshadow the expected Supreme Imperial Parliament, which, leaving the control of individual States to their respective legislative bodies, will deal only with matters of world-wide interest, and will so guide the destinies of the Empire that it shall everywhere grow in prosperity, standing fearless and impregnable before the whole world.

Original Signed Articles

The Cowlairs Incline Engine of the North British Railway.

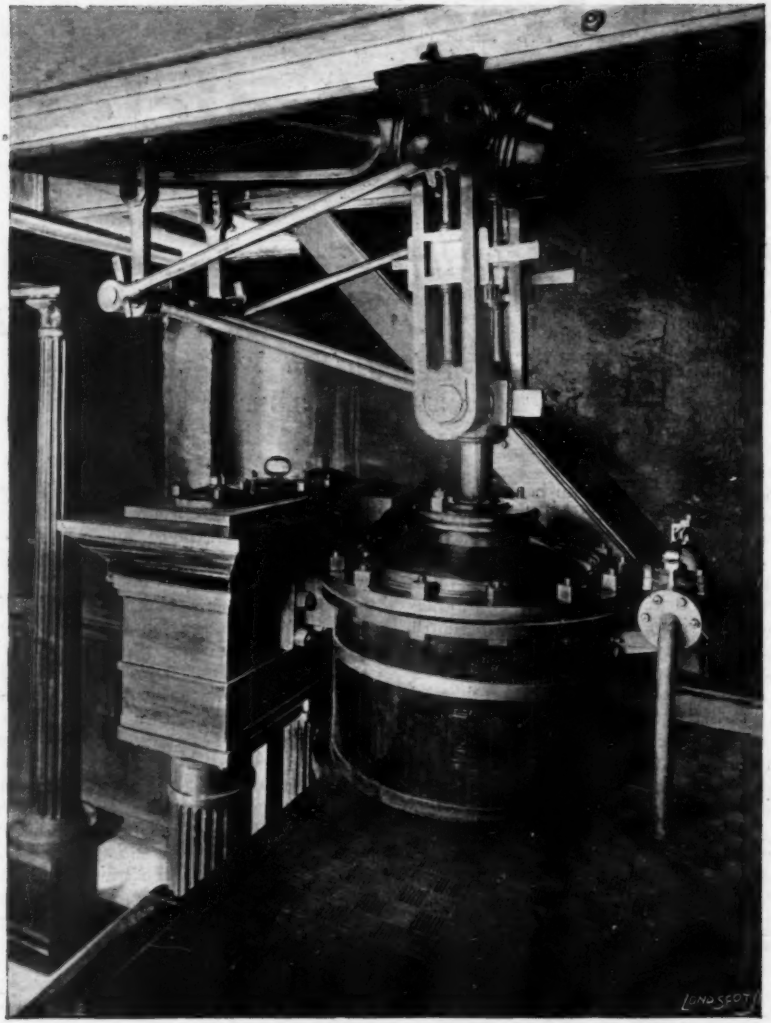
An Object Lesson in British Workmanship.

By BENJAMIN TAYLOR.

In these days when one hears so much of British industrial decadence, and of the superior craftsmanship of our American competitors, it is of interest to present the record of a memorable example of British excellence in production. All visitors to Glasgow by North British Railway are aware of the descent to the great city through a dismal tunnel, but few visitors know how they are hauled out of that tunnel again. And very few out of the circle of the Company's own staff are aware that all the work of the Cowlairs Incline is done by a standing engine which has been at work, night and day, with very few intervals, for sixty years. So splendid a record of excellent workmanship and of faithful work deserves to be set forth in some detail, and it is the purpose of the present article to describe a piece of machinery interesting as an example of past engineering, and unique in its experiences.

And at the outset the writer has to acknowledge his indebtedness to Mr. Holmes, Locomotive Supt. and Mr. Chalmers, Chief Draughtsman of the North British Railway, for their kind assistance in furnishing information and providing facilities.

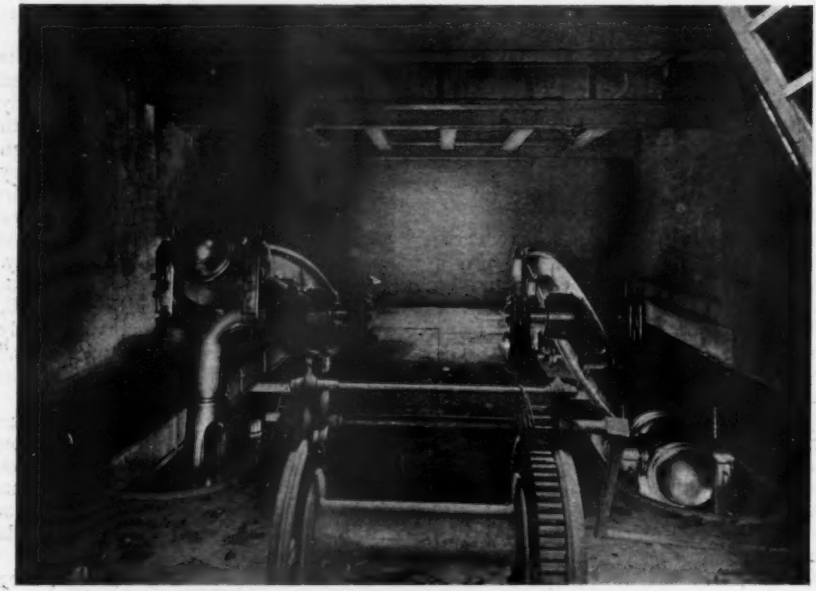
In 1840 the Edinburgh and Glasgow Railway Company began the construction of a line between the capital and the chief commercial city of Scotland. This line was opened in 1842, and was carried on by an independent company until 1865, when it was amalgamated with the wide-spreading system of the North British Railway Company. Until that amalgamation the eastern terminus of the Edinburgh and Glasgow line was what is now known as the Haymarket Station of the North British. Its western terminus was, and is, in Queen Street, Glasgow, which is entered through a tunnel down a steep gradient. At the top of the incline, but some distance from the mouth of the tunnel, is Cowlairs Station, from which the trains run down by their own gravity, with heavy brake wagons at the fore end, after the locomotive is detached. To haul the trains up the incline from Queen Street a wire rope is used, attached to the locomotive, which also exerts its power. For the working of this rope a stationary engine is placed close to Cowlairs Station at the top of the incline, and it is to this engine we propose to direct attention as one of the oldest and most interesting pieces of working machinery now in operation in Great Britain.



THE COWLAIRS INCLINE ENGINE: VIEW OF ONE OF THE CYLINDERS FROM INTERMEDIATE GALLERY, SHOWING PART OF BEAM.

The engine is of the double-cylinder high-pressure beam type, having cylinders 36 ins. diameter with a stroke of 6 ft. Steam is supplied from seven boilers at a pressure of 50 lbs. per sq. inch. The entablatures, columns, and pedestals are all of cast-iron; the columns are turned at their upper ends, and are accurately fitted and cottered into sockets bored in the entablature; all the centres are also fitted metal and metal, by boring and turning, and the beams and connecting rods are polished at their extremities, and

The present boilers, seven in number, and of the old Cornish type, which were put down in 1862–63, are placed in a house of their own adjacent to the engine-house, and a range of steam-pipes conveys the steam to the engine, where there are two stop valves—one for each cylinder—as well as the main throttle valve, which is worked by means of gearing with a horizontal wheel in a large bow window where the engine-man sits, so placed that he has a complete view of the line.



THE COWLAIRS INCLINE ENGINE: VIEW OF BEAMS, TAKEN FROM ABOVE THE CEILING OF THE ENGINE-ROOM.

are feather-edged throughout their length. On the crank-shaft is placed a large spur-wheel of 12 ft. diameter, with teeth of 4 ins. pitch and 1 ft. 3 ins. in breadth, and weighing about 15 tons. This wheel communicates its motion, by a pinion of the same diameter, to the pulley gearing by which the traction rope is worked. The engine and house are built upon solid rock, one of the reasons perhaps for its durability.

Engine and house are practically the same now as when they were first built, the only alterations being: that the cylinders were renewed about 1845, when their diameter was increased from 30 ins. to 36 ins.; the substitution of the town water for the supply originally obtained by means of two pumps, which worked off the parallel motion and pumped water into the tank at the top of the house (the pumps,

though still in their places, are disconnected); and that a very powerful strap-brake used to stop the engine after steam had been cut off, although still in its place, is not used now. In the engine-house there is a dial placed just opposite the position occupied by the man in charge, which indicates, per revolution of engine, the position of the train on the incline, and shows him when to shut off steam and leave the locomotive free to take up the running.

The piston-valves are of cast iron 10⅝ ins. diameter. The cogged wheels, one on the crank-shaft and one on the rope-driving shaft, weigh 15 tons each, and have each 88 teeth, precisely as they were fitted sixty years ago. The crank-shaft is 8 ft. 10 ins. long, and the crank-seats are 1 ft. long by 11½ ins. diameter. The engine develops 650 h.p., and the cable runs at a speed of 12 miles an hour.

Power is transmitted to the pulley gearing for working an endless rope by the spur-wheel on the crank-shaft. There were, in the first instance, two speeds, of the approximate rates of 12 and 20 miles per hour; but the slow speed is dispensed with, the speed required being now secured by the regulator wheel. The direction the rope takes when below ground is guided by several pulleys, and all that is observable is the rope just outside the engine-house, which disappears in the 4 ft. of the up-road, and re-appears in the 4 ft. of the down-road. The rope coming up the incline disappears and passes with two-and-a-half turns over the main driving pulley, which is 18 ft. diameter, and has three grooves for the rope in its periphery. It passes one-and-a-half turns round another pulley 10 ft. in diameter, which leads it to the bogie pulley. This is 10 ft. in diameter, and is placed horizontally upon a bogie-framing set upon rails, which travels backwards and forwards a distance of 20 yds. Attached to the bogie-framing is a chain, which passes over a small pulley at the end of the rails and descends into a pit, suspending a weight of about four tons as a counter-balance to keep the rope always taut. After leaving this bogie-pulley, the rope passes round another pulley set horizontally for the purpose of reversing the direction of the rope, and after encountering another wheel which places it in line with the down-road, it comes out of the ground and descends the incline to Queen Street, where, near the mouth of the tunnel, it passes round a 10-ft. pulley, placed at a slight slant just below ground, which leads the rope once more in the centre of the up-road, whence it ascends the incline to the main driving pulley. The rope is endless, and all the machinery is entirely below ground—the only means of getting down to it being a trap door, commonly known at Cowlairs as the "bogie hole."

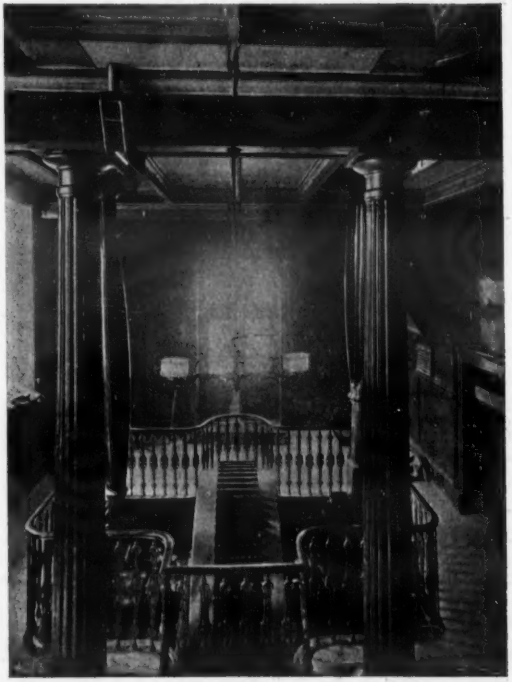
The rope is supported throughout its course by a series of guide pulleys pitched about 18 ft. apart. They were originally built of wood upon iron centres, with malleable iron spindles passing through them, which ran in brass bearings; they are now, however, of cast-iron, all cast in one piece. They last about 12 or 14 months, in which time the rope eats completely through the rim of the pulley. The rope was at first made of hemp, but this did not answer the purpose very well, and sometimes was unsatisfactory, especially during wet weather, when the "messenger," or chain gripper for attaching the train to the haulage rope, was apt to slip.

Since 1847 the rope used has been of the latest type. Each wire rope now lasts on an average fifteen months. It is 2·78 miles in length, 5 ins. in circumference, is all in one piece, weighs nearly 24 tons, and is made endless by splicing the two ends together.

The train is attached to the rope by means of what is called the "messenger," which is attached at the foot of the incline, just at the mouth of the tunnel. By turning the draw hook of the train-engine upside down, the necessity of stopping the train at the top of the incline is obviated. When the engine-man knows that the train is at the top of the incline the steam of the stationary engine is cut off, the rate of the rope decreases, the train runs over both rope and messenger, and causes the link of the latter to drop down from the draw-hook of the locomotive. To prevent the "messenger" from injuring or being

THE COWLAIRS INCLINE ENGINE:

FRONT VIEW OF ENGINE, SHOWING BEAM, CONNECTING RODS, AND COGGED WHEEL IN FOREGROUND, CYLINDERS IN BACKGROUND.



THE COWLAIRS INCLINE ENGINE:

VIEW OF COGGED WHEEL AND SHAFT FROM GALLERY.

injured by the guide pulleys on its path after being dropped, the road is laid with planking for about a hundred yards with slanting ways up each pulley (which are much broader in the rim than the rest), thus keeping the chain clear of the spindles, etc.

As all trains entering Glasgow stop at Cowlairs Station to collect tickets, there is no actual detention in detaching the engine, and substituting for the descent the incline brake-vans—two, three, or four being used, according to the length of the train. The engine, after pushing the train over the summit of the incline, returns to the sheds at Cowlairs; and the train descends to Queen Street in charge of brakesmen, who ride on the brake-vans, and regulate the speed of the train. Besides the brake power of the vans, the train is always charged with the Westinghouse, which, in case of emergency, can be applied.

Trains going up the incline proceed slowly to the mouth of the tunnel, where the man who fixes the "messenger" on to the rope, hooks it on the engine, which backs a little, just enough to let the haulage-rope get the weight of the train. The driver then whistles to the signalman, who telegraphs to the Cowlairs box. It takes from five to seven minutes, according to load, for a train to clear the tunnel, and drop the "messenger." Each train ascending has brake-vans in the rear, and can be stopped on the incline should the rope break.

The average train load is about 200 tons, and from 70 to 80 trains are hauled up the incline every day, except Sundays, when there are only a few trains in the morning and a few at night.

This venerable and vigorous engine is interesting from another point of view. It is one of the earlier products of the firm now known as Neilson, Reid & Co., Hyde Park Locomotive Works, Glasgow, now the largest makers of locomotives in the United Kingdom. This firm was founded in 1837, under the name of Neilson & Co., by Walter Montgomerie Neilson, a member of the family of the famous inventor of the "hot blast." It was, perhaps, more generally known in later years as the Hyde Park Foundry Company. It was a small establishment to begin with, devoted to the construction of land engines, of which this at Cowlairs is a type, as also a monument of the excellence of their workmanship. Some years after they began business, Neilson & Co. carried on several branches of engineering work, both land and marine, all of which, however, they gradually abandoned as the locomotive industry grew. In 1860, they left the Hyde Park Foundry for their present works at Springburn (not far from the site of our venerable friend), in which, however, they continued the name of their first establishment.

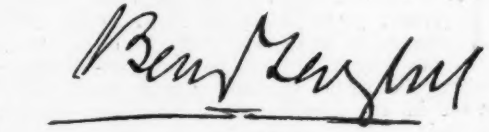
It is also of interest to note that the year in which this standing engine was erected at Cowlairs by Neilson & Co. was the year in which the predecessors of the North British Railway Co.—the Edinburgh and Glasgow Railway Co.—began to construct locomotives at their own engine-shops near Cowlairs. These shops now employ some 2,000 to 3,000 hands, on both constructional and repair work—chiefly the latter—but the Company still buy locomotives from Neilson, Reid & Co., whose predecessors built the old incline engine.

In 1844, the engine was stopped altogether, the managers thinking that locomotives would serve the purpose better. Four powerful engines were accordingly built at the Cowlairs Works, but the exhaust steam seriously injured the tunnel, and the engines, when wanted at Queen Street, were often at Cowlairs, and *vice versâ*. The stationary engine was, therefore, put into working order again, and it was at this period that the cylinders were increased in diameter, and an iron haulage-rope substitituted for the hemp one.

The engine was restarted on the 4th of March, 1847, and the four locomotives were removed altogether. It has run ever since, save for an occasional stoppage necessary for the renewal of the shafting, or from some other cause apart from the engine itself. These stoppages have been neither frequent nor very long, and when they have occurred, shunting engines have helped the locomotives to draw the trains up the incline.

The boilers now in use were built at the Cowlairs Works of the N. B. Ry., and, though forty years old, are sound and good for years of work still.

The tunnel is only wide enough for two lines of rails. It cannot be widened, nor the gradient reduced, without stopping the traffic altogether. The Railway Company will either have to construct a new tunnel, or, by making a *détour*, reach Queen Street by the east. In the latter (and more probable) case, the tunnel will be discontinued, and this is doubtless why the old engine is kept at work. It may serve as long as haulage is required on the incline



The Bursting of Small Cast-Iron Flywheels.

By PROF. C. H. BENJAMIN, M.A.I.Mech.E.

IN November, 1898, Professor Benjamin read a paper before the American Society of Mechanical Engineers on the subject of small fly-wheels, detailing the results of some experiments made in the laboratories of the Ease School.

The discussion of this paper and suggestions received from various engineers since its publication have led to further experiments on wheels of peculiar design. These experiments, which were all conducted under the immediate direction of Mr. Benjamin, who was present at most of the destructive tests, formed the subject of a second paper read by him before the same Society in December last, which is reproduced below in full.

The wheels, numbered 1 to 9 inclusive, were tested by senior students, while those numbered 10 to 16 were tested by instructors in the school. The wheels were all of cast-iron, 24 ins. in diameter, with proportions copied from existing wheels.

With regard to the general method of testing, former tests had shown the insecurity of a wooden shield or cage for the bursting wheels. Fig. 1 shows the form of shield used in the later experiments.

A cast-steel ring, 36 ins. in diameter inside, and having a rim section 4 ins. by 6 ins., was enclosed and supported by a wooden framework, the front and back being of oak plank 3 ins. thick. To absorb the energy of the flying fragments a sectional lining of Norway pine was used, as this could be easily repaired and renewed after each test. Fig. 2 shows the usual appearance after an explosion. During the sixteen experiments recorded but one wheel managed to escape from the shield, and this was due to the breaking of the bolts confining the side planking.

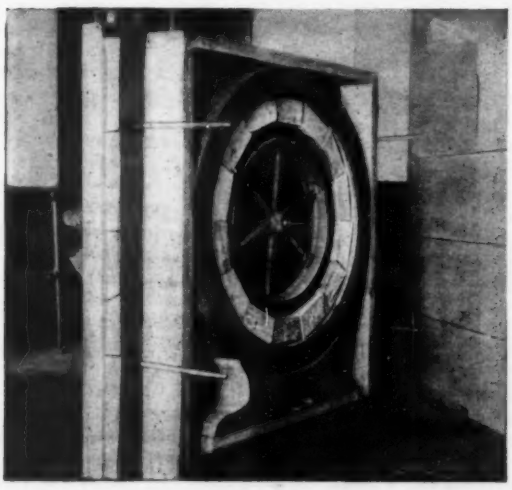


FIG. 1.

The wheels were keyed to the overhanging end of a steel shaft, $1\frac{7}{16}$ ins. in diameter, running in a long bronze bushing, and coupled loosely to a Dow steam turbine. Fig. 3 shows clearly the rear of the shield and the connections.

As may be seen from the cut, the speed was measured by means of a counter-shaft and belted tachometer, the speed being reduced in the ratio of 1 to 10. Belts made of two thicknesses of adhesive electric tape stitched together

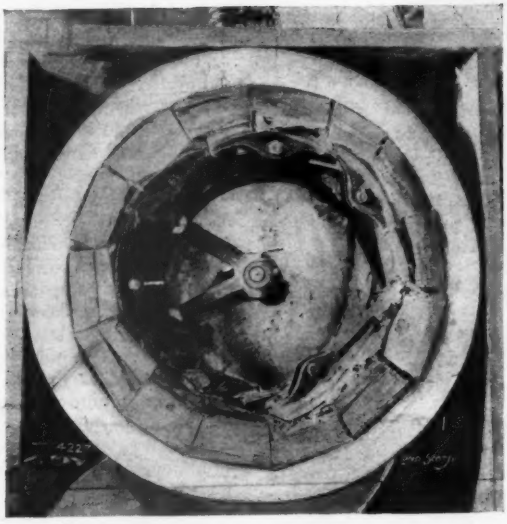


FIG. 2.

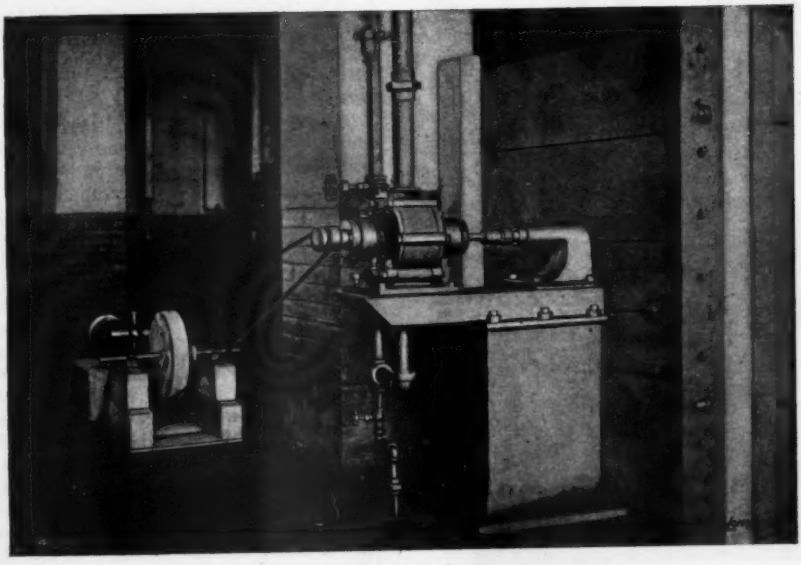


FIG. 3.

FIG. 4.

FIG. 5.

FIG. 6

were found to be satisfactory at the speeds used, being free from slip.

The speed-counting mechanism was calibrated many times, and showed an error of less than 1 per cent. All of the wheels tested were balanced carefully by winding lead wire around the arms close to the rim.

Wheels Nos. 1 and 2 were cast with solid rims, and were modelled closely from a fly-wheel 10 ft. in diameter on an Allis engine. These were tested to furnish a standard of comparison for the other wheels. Fig. 4 shows the shape and proportions of this class, and Table I. gives the principal dimensions. These two wheels failed at 3,700 and 3,850 revolutions per minute respectively, or at an average rim speed of 395 ft. per second. This corresponds to a centrifugal tension of about 15,900 lbs. per square inch. The fracture showed clean iron of a uniform quality.

The four wheels numbered from 3 to 6 each had two flanged joints in the rim, as shown in Fig. 5. These joints were of the same general proportions as those described in the previous paper, as may be seen by reference to Table II. They were located at points one-fourth of the distance from one arm to the next, those being approximately the points of least bending moment.

As shown in Table III., these wheels burst at from 1,800 to 1,900 revolutions per min., or an average rim speed of 194 ft. per sec. This corresponds to a centrifugal tension of about 3,750 lbs. per sq. in. These wheels were, then, only one-quarter as strong as similar wheels with solid rims, and burst at one half the speed. Comparing these with wheels of similar construction tested in 1898, we find that moving the joint from the centre to the quarter point has made no appreciable difference in the strength. This is, doubtless, due to the fact that the heavy mass of the flanges and bolts locates the bending moment at or near them. "Where MacGregor sits, there is the head of the table."

Fig. 5 shows the general manner of fracture of these wheels. Strange to say, the joints usually remained intact—the bolts

being slightly stretched—and the rim broke close to the joint, as shown in the cut.

The practically instantaneous character of the explosion is illustrated in Fig. 6, which shows the appearance of wheel No. 6 after rupture. With but one exception, each piece of the rim was embedded in the wood lining in its proper place, and remained there, indicating a nearly simultaneous movement of the fragments. The lining was rotated in the steel ring through a considerable angle.

The combined tensile strength of the bolts in the flange joints was about 20,000 lbs., or less than one-third the strength of

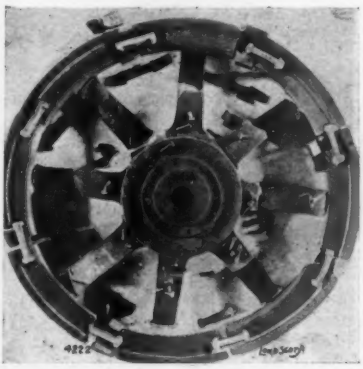


FIG. 8.

the solid rim, which is about the maximum ratio possible with this style of joint.

Wheel No. 7 was a complete working model of a fly-wheel for a blowing engine, and was copied from drawings furnished by a well-known firm of engine builders. The construction is clearly shown in Fig. 7, and the dimensions are given in Table I. The joints in the rim were carefully fitted and the links shrunk in. This wheel burst at 2,450 revolutions per minute, and a rim speed of 256 ft. per sec., which indicates a centrifugal tension of about 6,600 lbs. per sq. in., and shows that this wheel is nearly twice as strong as those just described. As may be seen by reference to Fig. 8, the wheel broke in every

FIG. 7.

instance through the smallest section of the rim near the joint, the links remaining intact. It is interesting to note that every bolt in the hub was shaved off clean as by a knife, each arm pulling out in this way.

Soon after the publication of the previous paper, the writer had some correspondence with Professor Archibald Sharp, which resulted in the latter's sending to America two model wheels to be tested, which are numbered 8 and 9 in the tables, and were constructed as shown in Fig. 9. The rims were solid, of an I

FIG. 9.

FIG. 10.

section, and were made of a close-grained cast iron, having a high tensile strength.

Each wheel had 24 spokes of steel wire, 12 on each side of the central plane. A pair of spokes constituted a loop, fastened at each end to the rim with a thread and nut, and passing spirally around the hub in a groove cut for that purpose. By tightening up the nuts at the rim the wheel could be accurately centred, and sufficient friction caused at the hub to prevent slipping.

The two wheels failed at precisely the same speed, 4,050 revolutions per minute, or a rim speed of 424 ft. per second. This would correspond to a centrifugal tension of nearly 18,000 lbs. per sq. in., and is probably the maximum speed attainable with a cast-iron rim. The appearance after rupture is shown in Fig. 10. The rims usually broke through the holes where the spokes were fastened, and the spokes themselves broke at one or both ends, where threaded.

The spokes had been adjusted to a uniform tension before the test by "tuning" them to the same pitch. This uniformity of tension, and the large number of spokes, must have prevented any

FIG. 11.

FIG. 12.

serious bending of the rims, so that the latter failed by direct tension.

The speed given is the highest attained in any of the experiments. One fact in connection with this last experiment deserves mention. It was found impossible at first to bring these wheels up to the desired speed; at about 3,000 revolutions per minute the speed would remain constant, and no increase of steam pressure would avail to change it. Becoming convinced that this was due to air resistance on the spokes and cross flanges of the rim, the writer had the wheels enclosed by discs of Russian iron, wired together and revolving with the wheels. No further difficulty was experienced, and

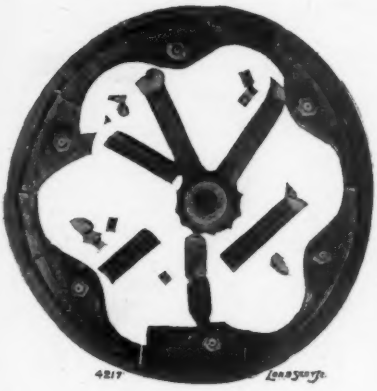


FIG. 13

FIG. 14.

the bursting speed was attained within two minutes of the time of opening the throttle.

Similar devices had to be used with wheels numbered 13 to 16 inclusive.

Wheels numbered 10, 11, and 12 had the usual flanged joints, located midway between the arms and fastened with four $\frac{3}{8}$-in. bolts. The joints in wheel No. 10 were unsupported, while those in wheels Nos. 11 and 12 were strengthened by steel tie rods running from hub to joints, and bolted at each end, as shown in Fig. 11. The net tensile strength of each tie rod was about 5,000 lbs. The two rods connected to each joint had then a combined tensile strength about two-thirds that of one arm. Wheel No. 10 burst at 1,570 revolutions per minute, a rim speed of 164 ft. per second, which is only about five-sixths of the speed usually attained by this class of wheel. The break was in the rim just beside the flange, and the low speed would indicate a poor quality of iron.

Wheels Nos. 11 and 12 broke at 2,100 and 2,200 revolutions per minute respectively, or at an average rim speed of 225 ft. per second. Comparing these with wheel No. 10, as the three wheels were of the same iron, and identical in every respect save the tie-rods, we find an increase of from 34 to 40 per cent. in the bursting speed due to the use of the tie-rods. This corresponds to an increase of nearly 100 per cent. in the strength of the joint. If the tie-rods had been more carefully designed and constructed a greater speed could have been attained.

Fig. 12 shows the appearance of wheel No. 12 after rupture. The ties broke through the bolt holes at one or both ends, the bolts remaining intact, with but one exception.

Wheels Nos. 13 and 14 were of peculiar construction, as may be seen from Fig. 13. The rim of each was cast in one piece, while the hub and arms formed a spider, also in one casting. The arms were jointed to the internal flanges of the rim by $\frac{5}{8}$-in. steel bolts, giving one degree of freedom. The object of this construction was twofold :—

(1) To relieve the bending moment at the junction of the arm and rim.

(2) By concentrating more weight near the arms to stretch these latter, and thus relieve the bending moments in the rim midway between the arms.

These two wheels burst at 3,650 and 3,850 revolutions per minute, or an average rim speed of 392 ft. per second. Comparing these figures with those given for wheels Nos. 1 and 2, we find that the speeds are practically the same. There is no apparent advantage in the special construction just described over the ordinary method of casting the spokes and hub with the rim.

TABLE I.—DIMENSIONS.

Number.	Rim.				Arms.		Weight of Wheel. Pounds.
	Diameter. Inches.	Breadth. Inches.	Depth. Inches.	Area. Sq. Inches.	Number.	Area. Sq. Inches.	
1	24	4·06	0·85	3·95	6	1·08	97·2
2	24	4·10	0·80	3·65	6	1·08	94·7
3	24	4·00	0·84	3·73	6	0·95	94·0
4	24	4·00	0·84	3·73	6	0·95	91·7
5	24	4·00	0·84	3·73	6	0·95	95·0
6	24	4·00	0·84	3·73	6	0·95	96·0
7	24	2·22	2·23	4·43	8	1·67	123·0
8	24	3·00	2·50	2·46	24	0·049	60·5
9	24	3·00	2·50	2·46	24	0·049	60·5
10	24	4·03	0·80	3·67	6	0·98	96·5
11	24	4·02	0·80	3·59	6	0·92	97·0
12	24	4·02	0·80	3·59	6	0·92	95·7
13	24	4·06	0·83	4·08	6	0·92	114·5
14	24	4·06	0·82	4·08	6	0·92	116·0
15	24	4·10	0·56	2·90	6	0·95	88·0
16	24	4·09	0·57	2·92	6	0·95	87·0

Fig. 13 shows the appearance of wheel No. 13 after rupture. The arms all broke at the eye near the rim, the bolts not being injured. Only one web was fractured. Fig. 2 shows the wheel immediately after the explosion, the front of the shield and one cover plate being removed. The embedding of the rim fragments in the wood lining in their proper order is clearly shown, the same as in Fig. 16. The absence of any tearing or rending sound, and the single sharp report, like a small cannon, also evidenced the practically instantaneous character of the explosion.

Wheel No. 14 was the one which escaped from the shield, as has already been noted. The wood lining was reduced to fine splinters, the cast-steel ring, weighing over 800 lbs., was rotated through an arc of 12 ins., a $\frac{3}{4}$-in. bolt was broken short off, and the 3-in. oak planking split and torn.

Wheels Nos. 15 and 16 were also of special construction, as seen in Fig. 14. The hub and arms were cast together as a spider, and bolted to pads on the rim. The two joints in the rim came over arms, and the rim between the arms was reinforced by elliptic webs. The construction

TABLE II.—FLANGES AND BOLTS.

Number.	Flanges.			Bolts.		
	Thickness. Inches.	Net Breadth. Inches.	Net Area. Sq. Inches.	Number in Joint.	Diameter. Inch.	Total Tensile. Strength.
3	1·0	2·4	2·4	4	·375	20,000
4	1·0	2·4	2·4	4	·375	20,000
5	1·0	2·4	2·4	4	·375	20,000
6	1·0	2·4	2·4	4	·375	20,000
10	1·0	2·4	2·4	4	·375	20,000
11	1·0	2·4	2·4	4	·375	20,000
12	1·0	2·4	2·4	4	·375	20,000
15	$\frac{5}{8}$	1·9	1·2	2	·500	18,000
16	$\frac{5}{8}$	1·9	1·2	2	·500	18,000

TABLE III.—BURSTING SPEEDS.

Number.	Bursting Speed.		Centrifugal Tension.	
	Revolutions per Minute.	Feet per Second.	Pounds per Sq. Inch.	Total on Rim.
1	3,700	387	14,980	59,000
2	3,850	403	16,220	59,000
3	1,800	188·5	3,570	13,560
4	1,850	193·6	3,750	14,000
5	1,900	199	3,950	14,780
6	1,850	193·6	3,750	14,000
7	2,450	256·5	6,600	29,400
8	4,050	424	17,970	44,000
9	4,050	424	17,970	44,000
10	1,570	164	2,700	9,920
11	2,100	220	4,800	17,200
12	2,200	230	5,300	19,000
13	3,650	382	14,600	59,600
14	3,850	403	16,300	66,500
15	2,080	218	4,800	13,900
16	2,175	228	5,200	15,200

is a slight modification of that suggested by Mr. A. J. Frith, of this Society, in a paper read in December 1890. The *raison d'être* of this form of wheel is explained by Mr. Frith in his paper. Briefly, this construction is intended to stretch the arms more and bend the rim less than the common form.

These two wheels burst at 2,080 and 2,175 revolutions per minute respectively, or an average rim speed of 223 ft. per second. Fig. 14 shows the manner of failure—the ends of the screws broke, sometimes the lugs on the arm, and sometimes the pad on the wheel. The rim usually broke at points midway between the arms. In wheel No. 16 the joints remained intact.

It will thus be seen that Nos. 15 and 16 were of practically the same strength as Nos. 11 and 12, but only about one-third as strong as wheels with solid rims.

The conclusions reached are: For wheels of moderate size correctly proportioned, the solid rim is by far the safest form, and will require a speed of from 350 to 400 ft. per second to produce rupture. The stress due to bending is so small as to be negligible.

Jointing the arms at the rim and bracing the rim by internal webs have no important effect on the strength.

Joints in the rims are the principal source of weakness, especially if located between the arms. Probably no joint can be made for a rim of solid cross-section, which will be more than one-third as strong as the rim itself.

Hollow rims will permit of a much more efficient joint, as has been shown by Mr. John Fritz in his paper, read at the meeting of this Society in May, 1899.

The joints in Mr. Fritz's wheel are practically as strong as the rest of the rim. This construction is hardly possible in wide-faced band-wheels, such as are used on most shop engines. Joints similar to those shown in Fig. 14 are probably the best that can be devised for this type of wheel. If joints are located midway between the arms they should be reinforced by tie rods leading to the hub.

The English wheels, Nos. 8 and 9, show clearly the advantage of numerous arms on any type of wheel. Even if the rims were jointed, such wheels would prove their superiority to those with the ordinary arms in maintaining their shape at high speed.

C. H. Benjamin

The New Education Bill considered in Conjunction with Technical Instruction and Foreign Competition.

By WILLIAM NAYLOR, F.C.S., A.M.Inst.C.E.

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RECENT discussions on the Education Bill, both within and without the Houses of Parliament, have been focussed virtually on pleas for justice to voluntary schools, improved facilities for secondary schools, and unity of control on the one hand; the impropriety of clashing authorities, depreciated School Board effort, taxation with only restricted control or no real representation, and partiality, yea, subservience, towards that religious body possessed of the greatest number of voluntary schools—the Anglican Church—on the other.

But accepting the inevitable, the triumphant passage of the Bill through both Houses, it is apparent on close consideration that if any real benefit is to accrue therefrom it will be in the provision by means of which a system of national education will be placed under the thumb, at any rate, of the public. The term "under the thumb" is used in the hope that this position at least will be conceded by all parties; but if not, then let it be said "under the gaze" of the public, for this is not to be denied. And experience suggests, too, that the "gaze" will be steadily fixed; for if it be granted that the Whitehall staff will inspect and apportion its share of Exchequer funds to each particular school, the existing school managers direct, and the man in the street simply put in an appearance for the minor part of the paying, even then this initially insignificant rôle on the part of the last-named actor must, in accordance with custom, evolve into the mainstay of the piece. Precepts such as are certain to be made will not be met for long without inquiry. In all municipal affairs those committees empowered with the greatest expenditure become the more important, are composed of representatives of the more powerful vested interests, and are subjected to the severer criticism.

Such noteworthy conditions, therefore, must attach themselves to the education committees as yet unborn, whether acting for urban, borough, or county councils; and should the powers with which they are vested be found insufficient to permit them to cope with circumstances at present unforeseen in a manner becoming such bodies of such men, it can only remain for both them and the electorate to insist on these powers being appropriately augmented.

In the history of both statutory and social innovations (changes of dynasty even suggest themselves) we are reminded that many of those received with forebodings of danger and disaster have upon trial, and by unanimous effort, proved to be of national benefit. Under the new educational *régime* elementary may be brought into closer touch with secondary schools, and there is a possibility of additional funds being available for the latter —in fact, for both.

During the past twenty years, and more particularly during the past ten, the popular cry for technical schools has been pronounced. Its accentuation in the last decade may be due to the keen industrial competition with this country on the part of Germany and the United States of America, and the very rapid increase in the factory output of these countries and other countries on the European Continent,

unaccompanied by a corresponding increase in Great Britain. Instances of commercial invasions, alleged superior productions and lower prices, have been seized upon and paraded by the daily press—occasionally by the technical press; and almost uniformly the injunction has been, Equip technical schools, imitate Germany, Belgium, and Switzerland, or this country is for ever lost. But pertinent to the moment is the question, Are industries suddenly developed by the agency of technical schools? or, on the other hand, are technical schools the natural sequence of recently developed industries? Should this not admit of a satisfactory and unfettered answer, then to what extent do recently developed and flourishing industries and technical schools depend upon or affect each other? And yet more important, what class of technical instruction will best assist old-established and unprotected industries?

That an exaggerated opinion exists in Great Britain cannot be doubted, and its existence is fostered by both the Continental press and Continental traders, concerning the extent to which the rise and the remarkable growth of German industries particularly are attributable to specially expert information or to superior scientific competency. In his report for 1895-6 the United States Minister of Education seems to have been as much led astray on this point as most people, for the chapter therein on German schools begins:—

"When in 1806 Napoleon defeated the army of Prussia the Prussian Government, prompted by Queen Louise, resolved to regain its power and influence by quickening the intelligence of the people."

This statement introduces the general contention that the very recent development of commerce is due to a similar recent development of technique, or applied science. But however much the intelligence of the people had been quickened in the year 1806 or those immediately following, it was not until seventy years afterwards that they were sufficiently intelligent to persuade capitalists to exploit the natural resources of the country, albeit other countries less favourably situated as regards mineral wealth, and not particularly well equipped with technical schools, had been sending therein right through this time minerals such as are now won and manufactured goods such as are now produced there. And while fully admitting that during the thirty years immediately following the date in question (1806) some progress may have been made in national education, it could only have been in the humanities; and, unlike technology and craftsmanship, with the accompanying apprentices and trade connections, likely to benefit the generation actually taught more than its posterity.

Indeed, the Governments of the various States at that time used almost every endeavour to thwart national progress, being too fully occupied in attempting to maintain their individual independencies to devote much time to matters of education. Questions of the hour when Frederick William IV. succeeded in Prussia (1840) were freedom of the press, parliamentary representation, and a national army; and the outcry was for political freedom, national unity, constitutional government. Pending some irrevocable settlement with Austria, both that country itself and the whole of the German independent States were too insecure to entice wealth for investment in bricks and mortar or machinery—for the doing of that which had long been done in England. Even after the unification of the North German States real estate was not considered secure, and foreign stock was only exchanged for it by those in close touch with Bismarck's policy. The announcement of the secret treaty with the Southern States and the Franco-German war declared the stability of affairs; but it was after the confederation of the Northern and Southern States that the hitherto dormant resources of Germany were taken in hand by capitalists, backed by a Government with a huge war indemnity in hand, and with credit unparalleled in its history.

The determination of Bismarck to arm, and arm thoroughly, religious disturbances, and socialist troubles permitted of no great strides for a few years. The copying

of British smallwares was the only work undertaken. Labour was cheap, it is cheap still. Herein lies the effective pinch of German competition, rather than in protection. In the late seventies emigrants were being shipped to America (the numbers increasing gradually from 22,000 in 1873 to over 200,000 in 1880) at an enormous rate, to reside there in cities, that such emigrants were unskilled labourers notwithstanding. How was it they could live in the United States comfortably and not in the Fatherland even miserably?

The commercial policy of Bismarck was, it has now turned out, more important to Great Britain than his Consolidation policy. Messengers specially despatched discovered that the cheap German labour could be used on machines in the United States with some little training, to which training the German emigrant quickly and assiduously applied himself. In the year 1876 therefore, after the "cheap and nasty" cablegram of Professor Reuleux to Bismarck, it was decided to seize the cheap labour for home consumption, and that a better class of ware should be produced. The country had energy, hard cash, credit, untouched mineral resources, and abundance of cheap labour, but practically few factories of magnitude—only a number of little workshops. Bounties on various exports, bonuses on production, State loans for works equipment, coupled with protection, would suffice for the creation of but not for the permanent support of competitive industry. For the turning out of better products either craftsmen or special machines were requisite. A choice had to be made between the English custom of relying on skilled artificers, or that of the United States of relying on machines and machinists.

Everything was in favour of the American system, for neither general all-round machine tools nor early types of textile or special trade machines had already been installed extensively. In acquiring its trade, at that time growing quickly, the United States had been called upon to invent automatic contrivances for facing high-priced labour, and had the more successfully accomplished this by isolating particular articles of manufacture at the expense of throwing on the scrap heap a considerable amount of mixed equipment. But the position of Germany was now unique, entailing simply a start with a free hand, and under the best of conditions, in the matter of raw material and labour. English models and American methods were the order of the day, English methods being of less importance except in the organisation and control, for which purposes foremen and overlookers were imported. But even machinists required some little training, it was found; and then, for the first time, trade schools and technical schools began to increase and multiply, and the *ebb* of the emigration tide has continued since.

But that country, Germany, which, according to popular precept, has been latterly so far-seeing as to have been able to discern the immense value of technical education when others were blind, and to have grasped the situation in such a progressive spirit, was possessed of a fairly exact knowledge concerning its utility, under ordinary conditions, for many years before it dreamt of being placed in such peculiarly favourable circumstances for its general dissemination. The Mining School at Klausthal was founded in 1775, enlarged in 1811, and styled the "Berg Academie" in 1864. The Berlin Trade School (Gewerbeschule) was founded in 1821, that of Chemnitz in 1836, while that of Hanover had in 1831 eleven teachers and fourteen lecture courses.

It is shown, moreover, by Herr Lüders, in his Memoranda on the Development of Industrial Trade Schools and Continuation Schools in Prussia, that the mushroom-like development of trade schools took place between the years 1880 and 1890; and if this report be studied carefully, together with the reports of the States Statistical Bureau, it will be observed that the increase of these schools and students, as well as students at the "Hochschulen" and University Technical Sides, has been in the *wake* of, rather than in the *van* of, commercial prosperity.

Statistics are, as a rule, repugnant to general readers, but the following will probably be pardoned in this connection :

	Total Consumption of Pig Iron in Germany—Tons.	Total Mining Produce of Germany—Tons.
1873 to 1880.	Fluctuating between two and three millions each year.	Fluctuating between fifty-four and fifty-eight millions each year.
1880 to 1890.	Steady and uniform rise to four millions.	Steady and uniform rise to ninety-five millions.
1890 to 1900.	Steady and uniform rise to eight and a-half millions.	Steady and uniform rise to a hundred and seventy millions.

During the last two decades, too, the increase in imports of raw cotton, wool, grease, and materials used in manufacturing processes has been similar; and to peruse the actual returns, in conjunction with Herr Luder's report, throws considerable light on the real *dêbût* of the trade and technical schools.

The object of the former has been undoubtedly to teach raw, untrained youths to handle and understand mechanisms during that period of their lives when in this country they would have been acquiring adeptness in the use of craft tools.

At the same time the Universities and Hochschulen have been turning out technologists, architects, and chemical engineers capable of laying down new factories, equipping them in the most recent fashion, and running them economically. The opportunity to do this has been absent, it is claimed, by hundreds of British manufacturers having hundreds of thousands invested in plant paying at least something. Probably 90 per cent. of the traders in this country would gladly grasp the opportunity of shutting down their existing factories and building on quite different lines.

In such a case they would be provided with well-lighted, warmed, and ventilated shops, in place of damp, dark, low buildings with earthen floors. Heavy and cumbersome lines of shafting, calling for frequent alignment and extensions, wasting energy when only few workmen are drawing upon it, would be obliterated, and each machine or group of machines would be driven by an independent electric motor. The old-fashioned hand-fired steam boiler would be augmented in capacity, and provided with automatic smoke-consuming stokers, feed heater, and super heater, or be replaced entirely by a gas producer, converting heat energy into the more manipulative electrical energy, and recovering at the same time the ammonia of the fuel now sent to waste. Steam turbines, or the most economical compounding engines would replace older types that have done duty for the present owners' fathers or grandfathers, and special machines for almost every article produced would be provided.

These are the favourable conditions under which the German syndicates, now asking for the re introduction of bounties, pay 20 marks per week for skilled labour, and 14 to 16 marks for unskilled, as compared with 30*s.* to 38*s.*, and 18*s.* per week of shorter hours for similar commodities in Great Britain. But one must in addition credit the Continental Teuton with that perseverance and inexhaustible patience which stand him in such good stead.

The foregoing observations do not, of course, apply to every branch of industry.

Shipbuilding, bridge designing, the art of forging heavy parts, erecting, and similar work can be learned from no text-book, nor in any technical school. In these matters advantage has been taken, to an unsuspected degree, of British yards, British capital invested in Germany and on the Continent having been instrumental in providing openings here for Continental practitioners. The following advertisement, which appeared in a recent

number of a leading engineering journal in England, is a common one:

MIDDLE-AGED SHIPBUILDING ENGINEER; German Subject; Wanted by large Dockyards; must have had several years' experience as Engineer for War and Mercantile Ships. Address, with copies of testimonials . . . care of . . . . Berlin.

Though the call may be for *one*, the *called*, as well as the applicants, may be, of a truth are, many, and Great Britain must be alive to its interests herein, or she will be surely caught napping.

In the United States the system of specialising is developed even further. There labour demands four times the price of German, and twice that of British. The machine, rather than the man, is therefore the ruling element, and the former has been brought to a high pitch of perfection, necessity being literally the mother of invention; and since the more complicated the machine becomes, the less fitted is it for the production of more than one article, repetition work is the order of the day. Not only one machine one article, but one factory one article. Hence such firms as the Cushman Chuck Co., The Carpenter Tap and Die Co., Reeves Pulley Co., Morse Twist Drill Co., etc., and an advertisement like the following taken from an American engineering paper:

"Don't go on making your own gauges. In this shop we make nothing else, and can make them cheaper than you."

Such shops are, as a rule, run by Scottish foremen, English mechanics, American machinists, and Irish labourers. After running for a few years the output is considerable, and at any time the complete clearance of the existing machinery, and the substitution of another type with, say, 25 per cent. greater output, is a matter undertaken without hesitation. Under these conditions the stocking of raw material at convenient opportunities for buying entails no risk, the piece-work or premium system of wages is easy, and the cost of foremen reduced to a minimum; no time is taken up in preparing for or getting into the swing of new work, and the chances are that the one article made is the best that *can* be made. In heavier work, too (iron and steel production), enormous capital has been invested in gigantic labour-saving appliances for raising ores, feeding furnaces, handling material, and transporting finished products, on the certainty that a judicious distribution of the almighty dollar would obtain the vote, if necessary, for protective tariffs sufficient to ensure a reasonable return. Hence raw material goes in at nothing less than English prices plus freightage, the struggle being left in the workshops. Here again the European Continental cheap labour comes in an easy winner, for European Continental iron furnaces are being similarly but more cheaply equipped. A recent issue of the *American Machinist* contained the following:

"TO EXPORTERS OF MACHINERY TO RUSSIA.

The . . . . Manufacturing Company Limited at . . . . begs to inform American makers and engineers who might be desirous of having their products manufactured in Russia itself, that they are prepared to undertake any orders which they might entrust to them. The . . . . Foundries include a cast-iron and steel foundry, and newly fitted up works, with all the most modern appliances—including a large quantity of American machine tools—for constructing machinery of every description. The arrangement enables the Company to undertake under the most favourable conditions the manufacture of every description of machinery, machine tools, agricultural machines, and specialities of all kinds.

Address communications to—

. . . . . Brussels, Belgium."

Now this advertisement read between the lines simply means that Belgium and German syndicates, having shops equipped with American machinery (made in Europe, in all probability) are seizing their opportunity. In many cases both British and American money is in the syndicates. It means that a first-class British or American firm may supply a plan or design of an article or manufactured product and have it executed just as well in Germany or the neighbourhood, and shipped to any point, ready for the trade-mark or name-plate. Within the author's knowledge this is done.

Can the new Education Act be used in any way to help matters here? I submit it can, in preparing the way for the gradual adoption of those methods of production which must obtain in the future. A complete industrial revolution cannot be realised suddenly, inasmuch

as mills and factories must be kept running, and the requisite capital and spoliation of capital already invested is another serious consideration.

To what degree other European Governments have assisted the banks, or manufacturers directly, is not publicly known, and probably never will be; but even were any department of the Home Government prepared to grant loans for the re-equipment of works or factories on the same lines as Colonial Governments assist the development of their territories by loans for agricultural equipment, it is probable that those traders who have already, with commendable foresight and business tact (in some cases after expensive inspections in other countries), reorganised their establishments in accordance with the most recent practice, would resist State aid to their less energetic competitors. Though such resistance might be met by the maxim that "the strongest and most powerful states are those whose inhabitants are the most prosperous," the necessity for such action has not yet really arisen. The primary step may be taken by the educational authorities, in the establishment of manual training schools for youths up to the age of sixteen, wherein shall be taught the manipulation of machines, and mechanisms studied.

After the suggestion in the earlier part of this article that a fictitious value has been accorded generally to the Continental technical schools, it may be urged that the advocacy of such a step is self-contradictory. The contention, however, was simply that the Continental technical schools and trade schools were aids to industries, suddenly developed under unusual conditions, and conducted on a system not hitherto practised. This development being now accomplished, and the system being now in operation to our detriment, it has become necessary, surely, to alter our practice to meet the conditions existent.

These conditions demand serious and prompt attention. The industrial progress of the twentieth century must be for Great Britain as much in advance of the nineteenth, as that of the nineteenth was in advance of the eighteenth, if her position and influence among other Powers is to be maintained. Unfortunately, he who attempts to disturb the national self-satisfaction is generally deemed a pessimist, and is confronted by the time-honoured dictum, "But we are not gone to the dogs yet." The inbred feeling of safety and superiority is probably based on the vast wealth of the nation, its achievements of the last six centuries, and the confidence a Briton feels in measuring himself against the representative of any other nationality. But will these suffice to-day? With the expansion of the Empire just complete, the means of maintaining it in danger of being wrested by the United Sates or Germany, or Russia even, this sense of security must be based upon something tangible. It may be doubted whether the achievements of the past six centuries will not form the very rock on which British commerce will split.

Since the days of Feudalism the English masses have been firmly imbued with the safety of leaving control, direction, formulation of general policy to their leaders. For meeting all difficulties each century has provided its leaders in abundance, leaders who have been successful in inspiring confidence and arriving ultimately at satisfactory issues. Had security depended to-day on the worldly wisdom, the fighting capacity, integrity, and honourable repute of born leaders all would be well. But the forty millions can only exist by "profit making," and with the cessation of profit making all assets are valued with a view to transportation only. Nor is this all. The class of leader in whom the populace has trusted through so many generations is not only unfitted by training and instinct to grapple with the question of commerce, but resents it. Hitherto commerce has supported him, his business being to assist in its protection, at the most, by force of arms rather than by conflict of wit. If he has engaged in it at all it has been at the risk of a social slur. An unfortunate result of this has been that many industrial concerns founded at the beginning of the last century were at the end of it in the hands of juniors much more desirous of joining the equestrian ranks than facing the difficulties of

re-organisation. The displays they were able to make of hunters and grouse moors obtained by profits secured in the absence of international competition persuaded the investing public to confide in prospectuses *re* flotation, and now the shareholders, having paid for dilapidated concerns once, permit the trade to go rather than pay twice. The monotony of this procedure is relieved by one or two instances where the prospectuses boldly went for re-organisation and re-construction on competitive lines, and these serve to prove the general contention, for cases can be cited of a few companies reformed during the past five years with factories on fresh sites, well equipped, sending into the heart of Europe and America products of real British type—unequalled for design, workmanship and wearing capacity. But these markets will not remain open long. The Colonies, the "Yellows" and "Blacks," may be supplied if an effort and some sacrifice be made.

As a preliminary, therefore, the educational authorities might well prepare for a general change of commercial equipment and procedure.

This by no means implies the displacement of all craftsmen by machinists, and that we must lose the world-famed British mechanics and millwrights who perfected the work of Watt, Stephenson, and Boulton; world-famed as being able to work thirty-six hours on end, in case of need, and hit hard at the finish. These men have made it known everywhere that the Britisher is not content with a machine or engine that promises a short life; a mechanism that will not stand taking apart and putting together again, that to him, in fact, a goob job "is a thing of beauty." These traditions must be maintained, and followed in beating competitors under the new conditions. While a good number of those men must still be trained, in the future fewer apprentices will be needed, more machinists, machine designers and improvers. To know the British mechanic is to admire him. Still, he prides himself mainly on his ability to file straight, chip evenly, line out flawlessly, adjust accurately, to know when to leave a joint as sound, and to send in a job exactly to order, though he may take his own time over it. That the same job can be completed on a machine by a youth in about half the time is to him only a sign of the senseless craze at which the Yankees are running things. But the Fates are against him. He must either take another machine or join the limited ranks of the repair gang. The glory of the file, the hammer, the straight-edge, and square has departed before the emery wheel, the pneumatic hand tool, the planer, shaper, and specialised automatic machine. Apprenticeships may therefore be shortened, and school days lengthened. In the elementary schools such subjects as Latin, botany, music, and the like, might well give place in industrial districts to manual training, the English language, and arithmetic.

Desirable adjuncts to the Education Bill therefore would be clauses to the effect that:

(1) Educational authorities in manufacturing districts shall have power to form Manual Training School Joint Committees, subject to the approval of the Educational Department at Whitehall.

(2) On such Joint Committees manufacturers shall be represented on a basis of ratable value, output, and number of hands employed.

(3) The Joint Committees shall have power to build, equip, and maintain special trade schools, and to frame and to put into force, subject to the approval of the Education Department, byelaws cencerning compulsory attendance, exemption, and leaving certificates.

(4) All work produced in the training schools on machines, or otherwise, shall have the labour value plainly marked upon it, calculated by the operative, based upon the prevailing price of labour in countries on the European Continent, where similar work is executed. Expert machinists capable of demonstrating the maximum output of the

machines, shall work continually in the training schools.

(5) Shall have power to equip and maintain Secondary Schools.

One effect of such schools, properly conducted would be to send youths into factories less amenable to the teachings of their shop mates anent uniform and standard rates of pay. They would have some knowledge of what their labour would sell at eventually, and, like workmen engaged on the production of wares sold at a known price in the immediate neighbourhood (brick and tile makers, locksmiths, boot makers), be inclined to contract for an increased output, or even to attempt co-operation rather than to strike. Their influence would make itself felt, too, on antiquated plant, and such trades as joinery, cabinet-making, the manufacture of tools, watches, hardware, guns, pumps, electrical appliances, would feel the benefit first. At a later period foundry work, boiler-making, paper and textile trades would be improved, and if then collieries and works dealing with heavy chemicals would only equip themselves, by some means, in a manner which would bring about a uniform cost of production, the whole of the preceding trades would benefit still further. As it is, those firms well equipped sell at a price to suit those badly equipped, a joint arrangement usually being entered into concerning the disposal of any surplus on the part of the former, and one or two branches of industry so placed affect the whole range adversely.

The assumption that a full and satisfactory re-adjustment of technological affairs would follow on the heels of manual training, is a false one, naturally. Secondary schools for the more advanced study of engineering design and economy would need to follow, the pick of the lower grade schools being translated thither. There the curriculum should include the measurement and various transformations of energy; machine design and the intelligent search of foreign patent specifications.

As specially emphasised by Mr. Levinstein in his recent address to the Society of Chemical Industry, efficient secondary educational institutions should run side by side with the elementary and manual training schools. In that address was placed, as the second chief factor "making for Germany's advance in industry and commerce,"—

"(2) The possession of a far larger number of thoroughly and systematically trained men than any other country (I do not mean of men only trained technically, but with a thorough general training)."

Now, since the factor to which that gentleman accords the primary position is—

"(1) Superior economy, thoroughness, attention to detail,"

which factor is really a resultant of that placed second, it follows that the order of the two factors ought to be reversed. Moreover, in a study of the causes which have led to Germany's advance, factor 5—

"(5) Cheaper skilled labour, with longer hours than ours"—

demands the primary position, apart from the foregoing reasonings, for the advance, *quâ* advance, might be made on low prices and the 40 per cent. commissions to London agents. Nevertheless, "general non-specialised secondary education" must be accepted as a burning question to be insisted upon to the age of 16 at least, after which age specialisation might begin in the secondary schools, divided for this purpose into three classes, Technical, Commercial, and Classical, with the following type of *curricula:*

Technical.	Commercial.	Classical.
English.	English.	English.
Mathematics.	Mathematics.	Mathematics.
Science (Pure and Applied).	Modern Languages.	Modern Languages.
Energy Measurement.	Commercial Law.	Classical Languages.
Factory Equipment.	European History.	History, Ancient and Modern.
Labour and Social Problems.	Geography.	Mental Science.
German Language.	Political Economy.	

While there is no apparent reason for the students from such classical schools possessing in a less degree those higher qualities inculcated in British middle-class and public schools, the chances are they would not entertain that self-satisfied feeling concerning the permanent stability of everything over which the Union Jack happens to be flying. As for the output from the other secondary schools, the following extracts from Prof. Wertheimer's paper, read at the recent London meeting of the Institution of Mining Engineers, are interesting:

"We come then to the need for technical training for the higher industrial posts; this must be given mainly, though not of course entirely, in day classes, and should, as a rule, precede entry on industrial life. It should be accepted in place, not of all, but of some part of a young man's apprenticeship in a workshop, a mine or wherever his sphere of action may lie. This, unfortunately, is not fully recognised in this country, though each year a small but increasing number of employers is willing to reduce the period of apprenticeship in the case of men who have had a thorough college training. In America and in Germany the case is otherwise, and employers in the engineering industries are willing to accept from trained students a much shorter apprenticeship than is asked in the case of untrained men. In this way they at once recognise and foster proper technical training. . . . . Take engineering; we had in the whole of this great engineering country only 347 third-year and 52 fourth-year students, making 399 in all. In a single German technical high school (Charlottenburg) there were more, namely, 477; and our 399 includes some students as young as 17, and many only 18, while all the Charlottenburg students were over 20, and more than half over 21.

"You will ask what are the prospects of young men who have been trained in these foreign schools, and who leave at the age of 22? Let us base our answer on actual facts taken from the statistics of an American institution, the magnificent Massachusetts Institute of Technology at Boston. . . . . 'Each year about 300 of the students—all over 22—leave the Institute after completing a four years' course, and the American employers value the training so highly that every one of these students is provided with an engagement before he completes his course.'"

From the practical workshops, then, in the technical schools (not pigmy huts containing a 10-h.p. model steam engine and a toy lathe) the students should have come prepared to recognise at once an extravagant power generator, an expensive or circuitous mechanism, or system of mechanisms, or a roundabout technological process of any description.

Scholarships therefrom should be tenable at works in the act of being dismantled and re-equipped, or in shops recently constructed on the most approved and systematised lines. Their weekly reports to the principal should deal with the output per ton of coal, per unit of energy, per yard of floor space, per unit of wage per man. Ten years' hard work in this direction would produce men competent to direct the energy, skill, and business capacity of British workmen into right channels, and to persuade them of the absurdity of quarrelling, as in the case, this year only, at the North Eastern Railway Company's works, as to which of the particular tradesmen should *carry work to* a machine, which should *put it through* the machine, and whether or not handy men or apprentices should be allowed to assist the boiler-makers in the operation or not. Until such disputes as these are regarded as curiosities of commercial ancient history, education in British schools is in its puking infancy.

It is to be hoped that representatives of British industry on all sides of the House will be induced to take this opportunity of coming to the aid of their country. Proper inquiry can only result in a finding that the danger is not chimerical. But the situation, though critical, is by no means lost. The men who years ago pushed our trade far ahead of all competition, left behind them a breed which, if properly prepared, is capable of overcoming all obstacles to-day. But the present equipment is as unfit for the purpose as was that used by the British in-

fantry against the Boer commandoes—just as thoroughly, just as expeditiously must it be amended; and it becomes the duty of all to "see this business through." No longer may fortresses or battleships ensure permanently the welfare of a nation not self-supporting. The production of wealth is a *sine quâ non*, and to this end now indeed is the time to "Wake Up!"

> "Methinks I see in my mind a noble and puissant nation rousing herself like a strong man after sleep, shaking her venerable locks; methinks I see her as an eagle muing her mighty youth and kindling her undazzled eyes at the full mid-day beam, purging and scaling her much-abused sight at the fountain itself of heavenly radiance."—MILTON, "Areopagitica."

W. May Lon. 4246

The South Wales and Bristol Direct Railway.

By OUR SPECIAL COMMISSIONER.

THE formation of a British-Canadian line of steamers which is at the present time in contemplation, as a rival to the American Shipping Combine, has had associated with it the name of Milford Haven as being the terminal port, on this side, which is nearest to Canada.

Its claims to suitability in connection with this scheme over and above any other port on the West Coast, cannot be too strongly urged, especially as, in the near future, owing to the enterprise of the Great Western Railway Company, the time saved in the railway journey from London to this port will be considerably reduced. This enterprise, known as the South Wales and Bristol Direct Railway, has been undertaken to save the long *détour* made by the present Great Western main line through Bath and Bristol to the Severn Tunnel. Of the latter the direct line may be said to be a complement, as by means of both a direct route to South Wales will now be possible.

A reference to the map will show that the main Great Western line commences at Wootton Bassett to make a sharp bend to the south, which continues until Bath is reached, whence it bears away again in a northerly direction to Patchway. The object of the scheme has been to make a fairly direct connection between these two points by which, not only will much better gradients and easier curves be obtained than by the route through Chippenham, Bath, and Bristol, but the distance into South Wales will be shortened by some eleven miles. The saving in time is likely to be in a greater proportion than is represented by this distance, owing to the fact that throughout the new length there will be no gradient of more than 1 in 300, and no curve sharper than 1 mile in radius,

MAP SHOWING DIRECTION TAKEN BY THE NEW LINE.

while on the old route the Wootton Bassett incline of 1 in 100 for 1 mile 550 yds., and the Box incline, including the passage of the Box Tunnel, also 1 in 100 for a length of 2 mls. 660 yds., both descending towards the Bristol end of the line, had to be negotiated by the up trains.

The other advantages which the new route will bring are the relief which will be afforded to one of the busiest sections of the main line, viz. from Bristol on through Bath; the additional access it will provide for the new Avonmouth docks; the opening up of a large tract of country in Wiltshire and Gloucestershire, comprising some twenty parishes, including the villages and towns of Brinkworth, Somerford, Hullavington, Acton Turville, Chipping Sodbury, Coalpit Heath, Winterbourne, etc., which have hitherto been unsupplied with railway communication; and, finally, an emergency route to South Wales, *viâ* the Severn Bridge, in the event of any breakdown occurring in the Severn Tunnel. Traffic in this case could be diverted to the Midland Railway, over which the Great Western have running powers, between Yate—at which point, as will be seen, a connection is to be formed—and Berkeley Road, and thence on to the Severn and Wye Railway, which is now the joint property of the Great Western and Midland Companies.

The general object of the railway was facilitated in its execution by the character of the country passed through, which is entirely agricultural, and presented no inducements to diverge, from a traffic point of view, through any particular district. On the other hand, the determination to provide the shortest route from point to point through country which, generally speaking, is heavy, involved a considerable first cost, amounting as it does to over £40,000 per mile.

Including the loops, the new line is 33½ mls. in length, and will involve at least 5,000,000 cub. yds. of excavation, with a quantity of material slightly exceeding this to be tipped for embankments.

Following the map and the longitudinal section, it will be seen that the new line diverges from the old main line a few hundred yards to the west of Wootton Bassett station, in a slightly north-westerly direction, and for the first 7 mls. 20

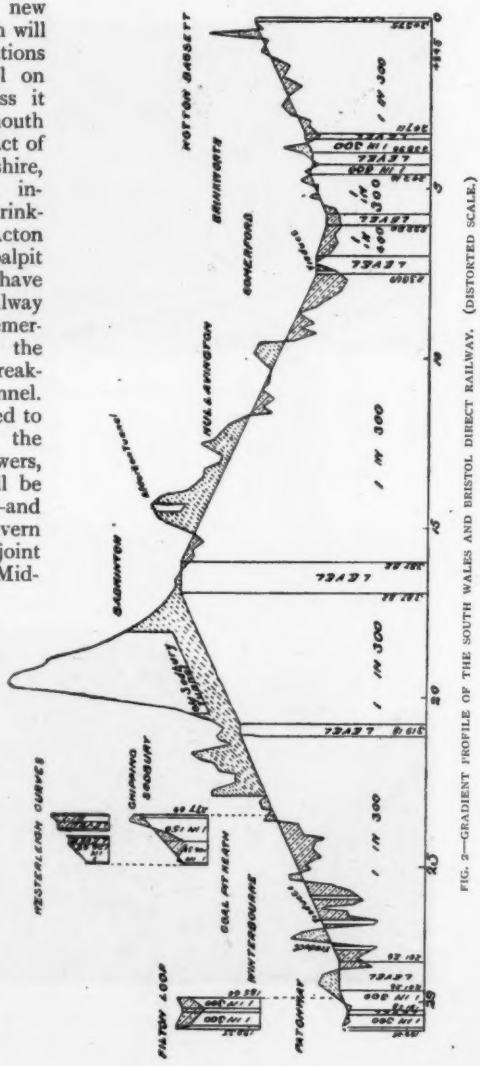


FIG. 2—GRADIENT PROFILE OF THE SOUTH WALES AND BRISTOL DIRECT RAILWAY. (DISTORTED SCALE.)

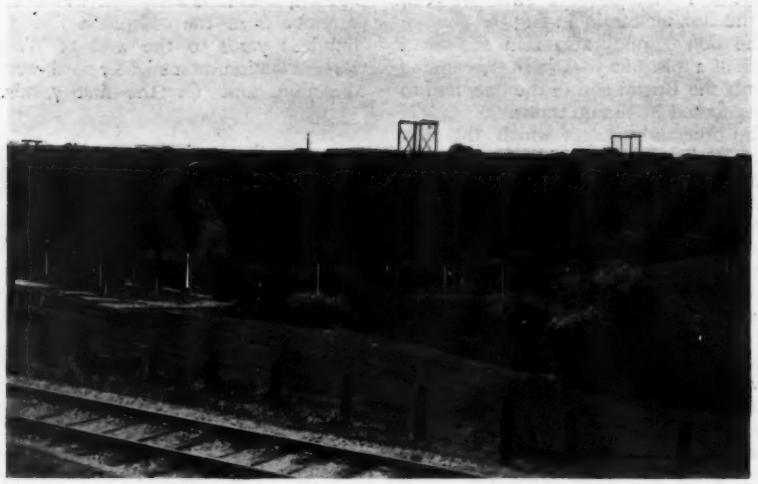


FIG. 3.—SOMERFORD VIADUCT UNDER CONSTRUCTION.

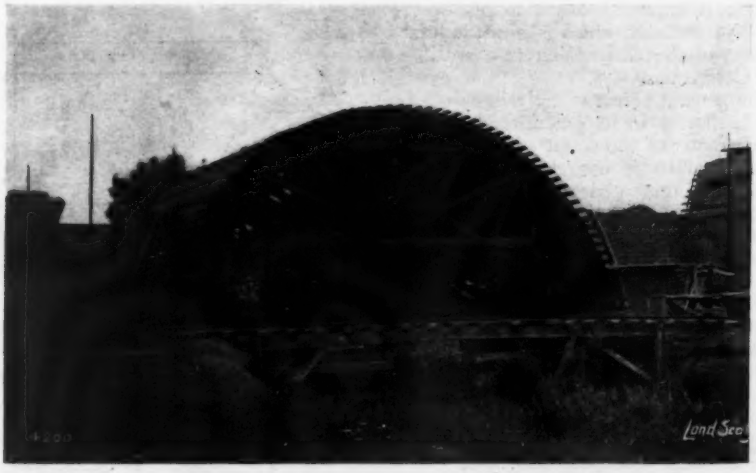


FIG. 4.—CENTERING TO RIVER SPAN OF SOMERFORD VIADUCT.

chns. is practically downhill at 1 in 300, with the exception of four short lengths on the level, and short rises of 1 in 600 and 1 in 400. This gradual descent, which terminates at the lowest point reached on the east side of the summit level, is due to the fact that the country here constitutes the watershed dividing the upper reaches of the river Thames and the Wiltshire Avon, the latter being crossed by the railway at the above-mentioned point.

The formation in the early portion of this section is chiefly Oxford yellow clay. This proved to be of a weak and treacherous character, causing a very bad slip to occur in the first cutting, necessitating the whole of it being run to spoil, and the slopes being trimmed to the unusual angle of 5 to 1. For practically the remainder of the first section the formation is chiefly Oxford hard blue clay, with oolite here and there; the slopes in the case of the blue clay being 2 to 1 and 3 to 1, while in oolitic rock they vary from ¼ to 1 to 1 to 1, according to the solidity of the rock and depth of cutting.

At Brinkworth—the inhabitants of which place have now to go to Dauntsey, some miles away, for railway accommodation—the first station is reached at 4 mls., and at 5 mls. 30 chns. commences an embankment which extends as far as 9 mls. 24 chns., and contains over 1,000,000 cub. yds. of earth and rock. At 7 mls. Somerford Station is reached, a point within 3½ mls. of the interesting old town of Malmesbury, now reached by a branch from the old main line.

Somerford Station, as will be seen from the plan, Fig. 5, is a four-line station, the diverging tracks being for the accommodation of slow passenger and goods traffic, the centre lines being reserved for fast trains. A span of 10 ft. as a minimum, and 11 ft. where it can be obtained, is provided between the main and loop lines, to permit of the erection of the necessary signals between the lines in question. The position of the signal box is controlled by the maximum distance allowed by the Board of Trade between the box and a facing point—viz. 200 yds.—and between the box and a trailing point—viz. 300 yds. The distance of the box from the rails and

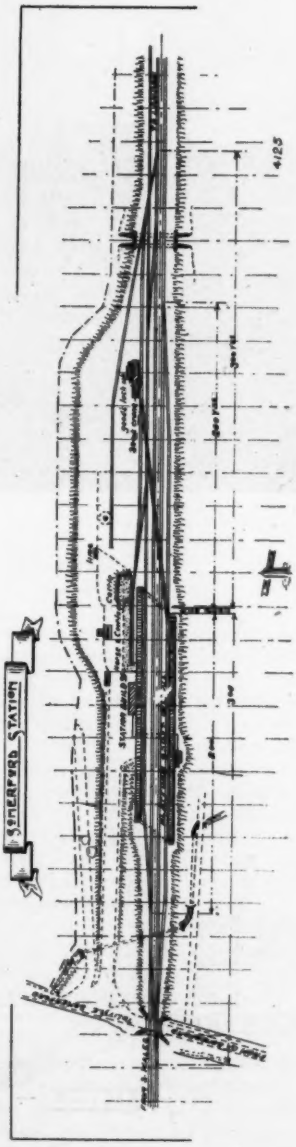


FIG. 5.—PLAN OF SOMERFORD STATION.

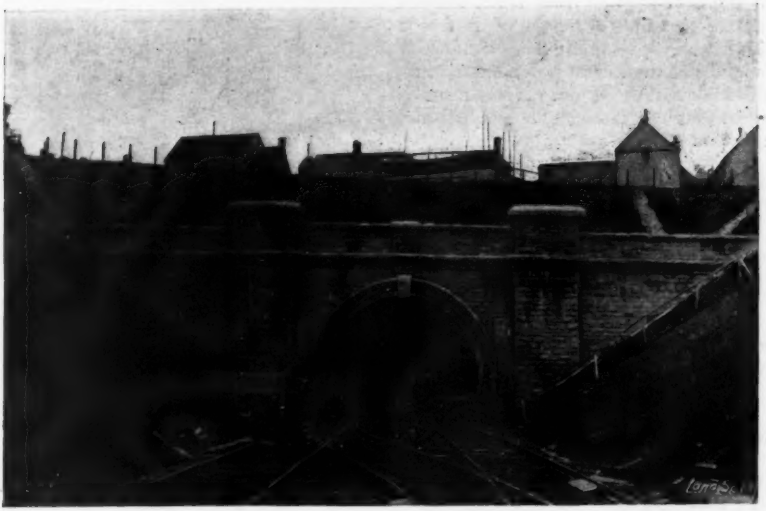


FIG. 6.—WEST FACE OF SODBURY TUNNEL.

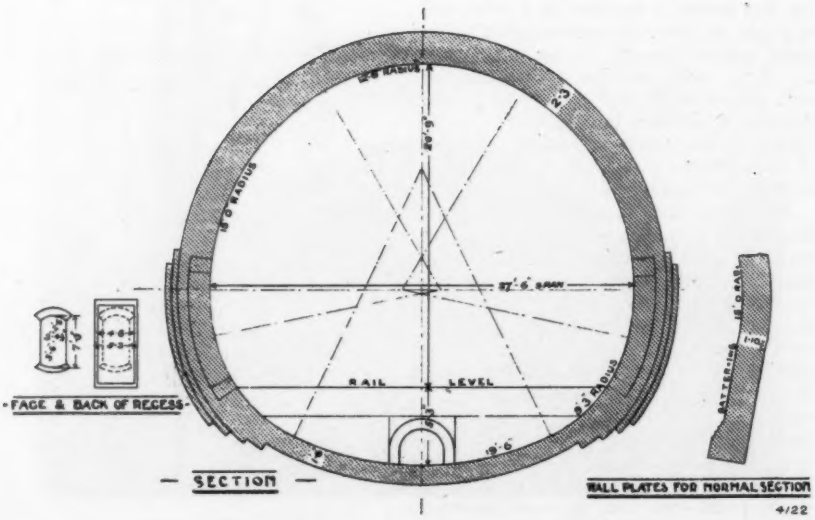


FIG. 7.—SECTION OF SODBURY TUNNEL WHERE INVERT WAS USED.

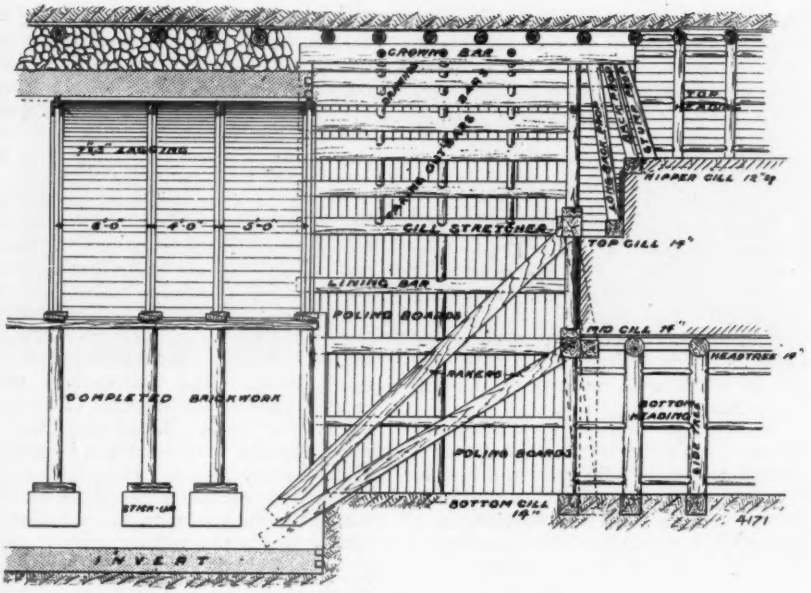


FIG. 8.—DETAILS OF TIMBERING, SODBURY TUNNEL.

its height have been regulated so as to permit of the best view of the various signals and sidings, etc. Practically, every other station on the new line is arranged in this way, and provided with refuge sidings to accommodate trains of 50 trucks. Ground has, however, in every instance, been acquired to enable these sidings to be extended to hold trains of sixty trucks.

Whilst on the subject of ground, it may be mentioned that the long bank above referred to—in fact, practically all the banks—have been tipped to provide for four lines of way, while sufficient ground has been acquired right through the route to provide this accommodation when necessary. It is the fact of the Great Western Railway having exercised the foresight in purchasing the extra strip of land, 25 ft. in width, which is necessary to add two additional tracks that has enabled the work to be pushed forward with so much rapidity, as the contractors have been enabled to make use of the extra width for their lines to bring up material, and so save time, expense, and extra cost of conveyancing, which would otherwise have been involved.

It will be noticed that Somerford Station, in common with all on the line, is not constructed on the modern principle of the island platform; the extra expense thus incurred having been justified by the fact that the outward sweep of the rails, involved where island platform stations are used, and which is not desirable where very fast running traffic is expected, has been avoided.

In the vicinity of Somerford Station, which is adjacent to the lowlands of Somerford traversed by the River Avon, extensive irrigation works have been carried out, consisting of a series of sluices intersecting the adjacent fields, which carry the water away from the embankment.

A few chains westwards brings the line to the first of several very important works, viz. the Somerford Viaduct (Fig. 3) which spans the above-mentioned low-lands and the River Avon. It is a

handsome structure, consisting of 12 spans of 25 ft. and one of 58 ft., and is built in brick, faced with Staffordshire brindles with springers, label course, strings and copings of ashlar. The largest arch is of 8 to 10 rings in thickness and is composed entirely of brindles. Fig. 4 shows the form of centering employed for this span. The rise of the arches is 10 ft. 9 ins., and the average height from the ground to the rails is 35 ft. The foundations are in gravel, and the river span (58 ft.) is piled on one side. Following the viaduct is a girder-span, carrying the line over the existing branch of the Great Western Railway connecting the old main line with the town of Malmesbury, distant about 3¼ mls.

The bridge over the Malmesbury branch marks the commencement of a gradual ascent of 1 in 300, which continues for a distance of 9 mls., culminating in the summit level of the line, at a spot immediately before the tunnelling of the Cotswold Hills is commenced.*

Section No. 2 of the line, reaching for 10 mls. 69 chns., is also entered at this point, and continues on the long bank before mentioned to 9 mls. 20 chns., which is succeeded by short cuttings, with light intervening banks, the line passing close to Bincombe Wood, a famous fox cover in the Badminton Hunt district.

At 11 miles, on embankment, is Hullavington Station, which is of the two-line type, with accommodation for goods traffic. Adjacent to this station, at a place called Kingway Barn, the contractors erected an extensive depôt, covering 10½ acres, in which the provision made for the men included a museum and reading-room. The brick-making plant erected here had a capacity of 100,000 bricks per week. Large quantities of earth material have been run to spoil at Hullavington.

The line here enters one of the heaviest cuttings in the whole length, extending for a distance of 4 mls., with a maximum depth

* The contractors divided the line into five sections: No. 1, from Wootton Bassett to Somerford, 7¼ mls.; No. 2, Somerford to Sodbury Tunnel, 10 mls. 69 chns; No. 3, Sodbury Tunnel, 2½ mls.; No. 4, Sodbury to Coalpit Heath, including branches junctioning with Midland Railway, or a total length of 5⅝ mls. double line of railway, and 1 ml. 33 chns. single line; No. 5, Coalpit Heath to Patchway, including the Filton loop, or a total of 5¾ mls. double line.

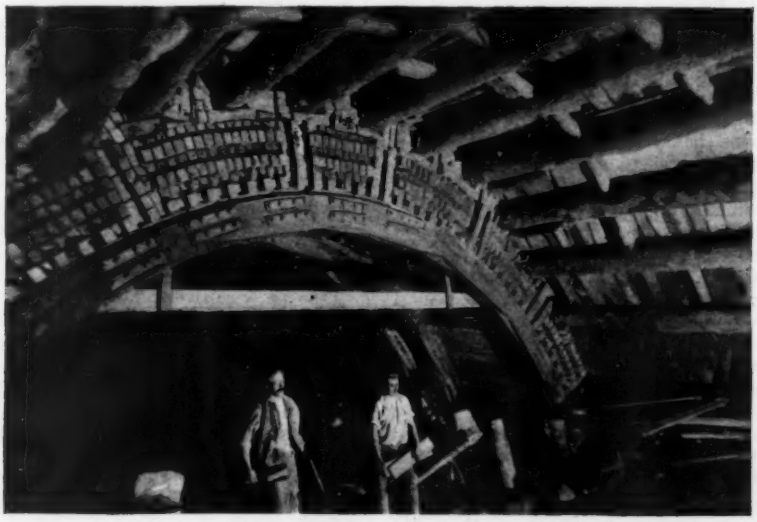


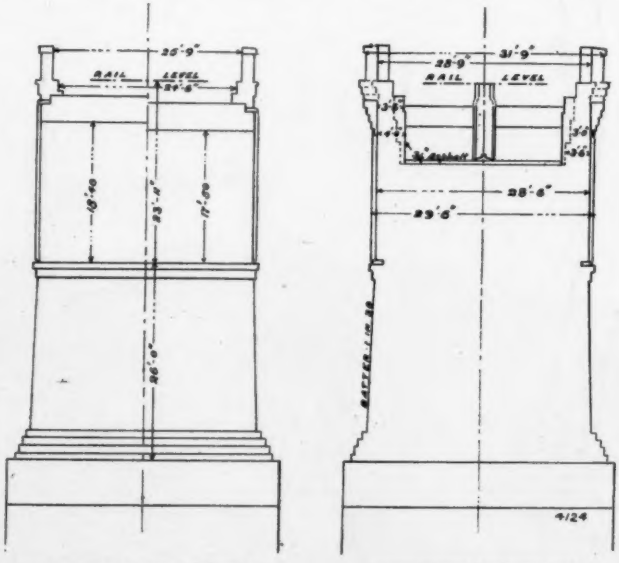
FIG. 9.—SODBURY TUNNEL ARCH AND TIMBERING IN BLUE SHALE.

FIG. 10.—BRIDGE OVER THE MIDLAND RAILWAY.

of 63 ft., and involving the removal of nearly 1,000,000 cub. yds. of material.

The geological formation through which this cutting pierces is the Great or Bath-onion oolite, consisting chiefly of blue shale, with clay, sandstone, and limestone.

As is frequently the case in the oolitic formation, water found its way to the face of the slope, where the shale and loose stone joins the underlying clay, with consequent drainage difficulties. This water, if allowed to run through the bottom of



CROSS-SECTION THROUGH CROWN OF CENTRE AND WEST SPANS.

CROSS-SECTION THROUGH PIER OF CENTRE SPAN.

FIG. 11.—BRIDGE OVER THE MIDLAND RAILWAY.

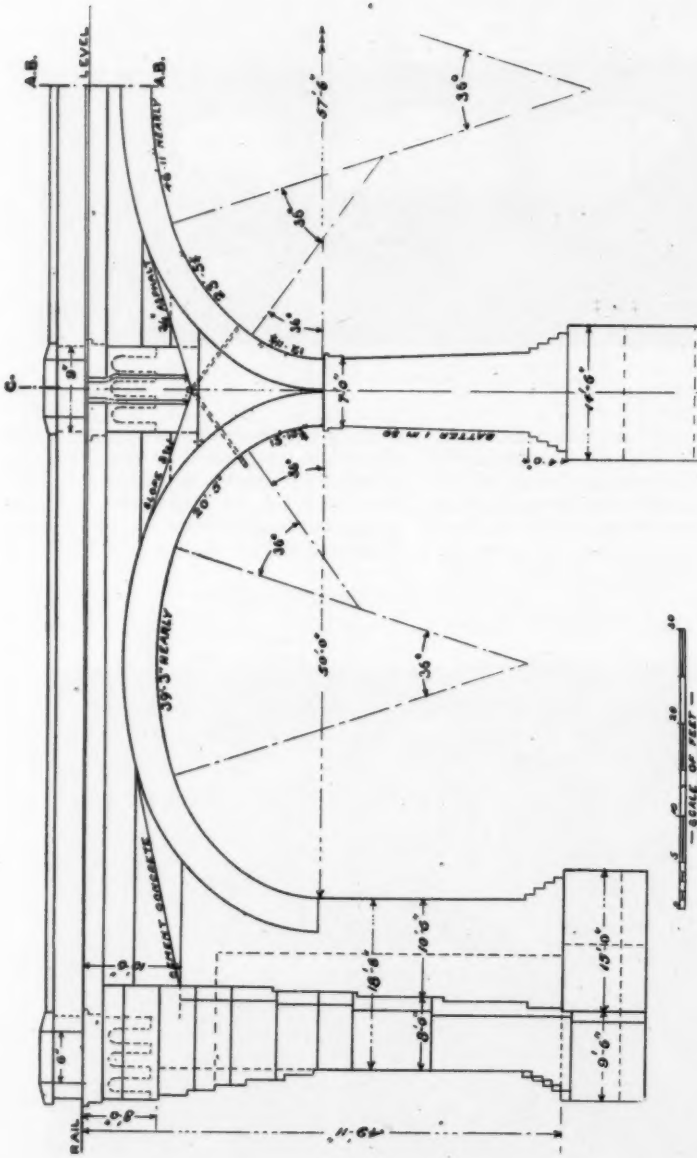


FIG. 12.—PART LONGITUDINAL SECTION OF BRIDGE OVER THE MIDLAND RAILWAY.

FIG. 13.—MIDDLE CENTRE FOR BRIDGE OVER THE MIDLAND RAILWAY.

FIG. 14.—WINTERBOURNE VIADUCT UNDER CONSTRUCTION.

the slopes, would in the course of time, eat away the clay and let in the rock above it; so to prevent this, a trench running parallel to the railway, and constructed with a slope to let the water into cutting drains, was sunk 12 ft. away from the top of the slope.

Retaining walls have in some places been put in to prevent the clay bed from bulging out.

At the deepest part of this cutting, Alderton Hill intervenes, which is pierced by a tunnel 560 yds. in length, in which remarkably little water was encountered. It was cut entirely from two shafts, 280 yds. apart, and 140 yds. from each open end, and not worked at the ends at all, and no rock drills were found necessary.

Work was carried on only in the daytime, and the progress made was 24 yds. per month. No continuous heading was driven, the excavation being removed length by length, and the brickwork built in. The walls are 1 ft. 6 ins. thick; the arch consists of four rings, and no invert was required. The cost per lineal yard worked out at slightly under £60. The faces are particularly well finished in Staffordshire brindles, red brick, and ashlar.

Succeeding the cutting at the western end is a shallow embankment, which becomes at 16 mls. 8 chns. level until Badminton Station is reached. It is this level stretch that represents the apex of the line at 387 ft. above ordnance datum. The main road from Bristol to Malmesbury is crossed by this length, as is also one of the avenues leading to Badminton Park, the seat of the Duke of Beaufort, which gives its name to Badminton Station.

It is the proximity to the residence of the Duke of Beaufort that will give Badminton Station a special interest to visitors who are in the habit of participating in the hunting which renders this district famous. The village immediately adjacent to this station is Acton Turville, but Badminton being so much better known it has been decided to adopt that name.

FIG. 15.—WINTERBOURNE VIADUCT COMPLETE.

It is a four-line station, and at one time it was thought to provide special rooms there for the use of hunters, but a new hotel, shortly to be built near by, will serve to afford the requisite accommodation.

This station will also serve to open up the charming district of its own neighbourhood, and that of Castle Coombe, which have hitherto been difficult of access from the neighbouring towns of Bath, Bristol, and Chippenham.

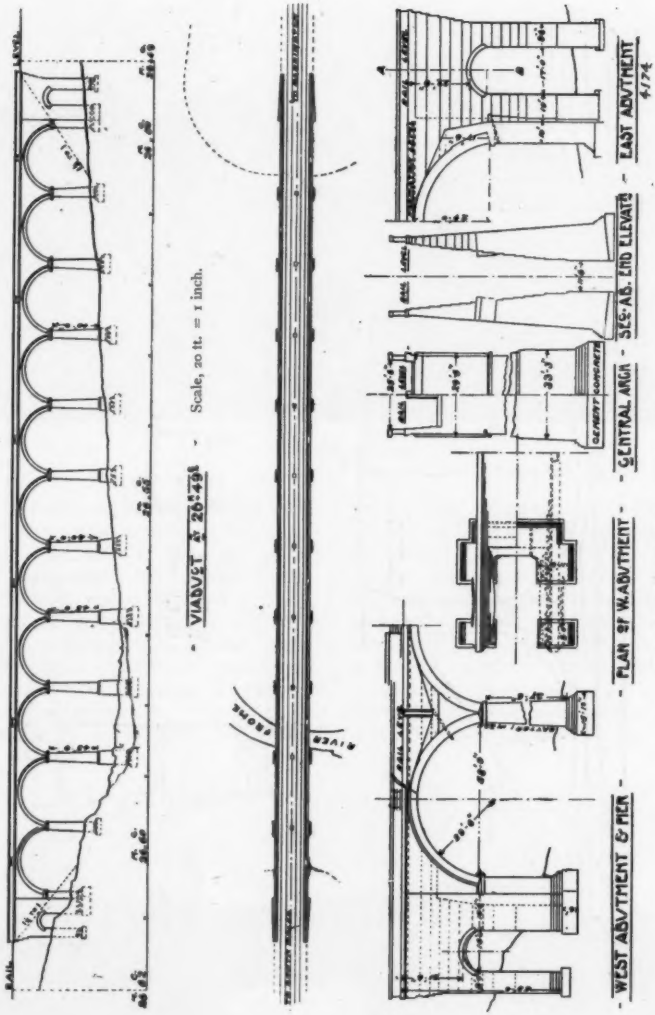
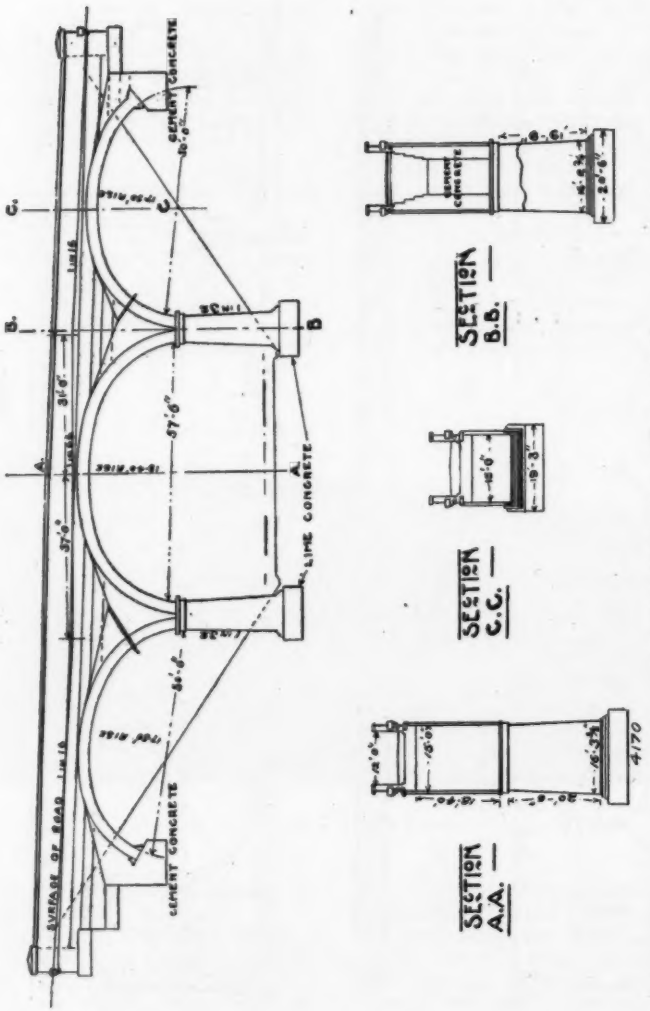


FIG. 16.—DETAILS OF VIADUCT AT HUCKFORD.

The gradient of the line is now again 1 in 300, in heavy cutting, piercing again the oolitic formation, in that sub-division known as the Forest Marble. About 410,000 cub. yds. represents the amount of excavation in this cutting, the maximum depth of which is 70 ft., with slopes varying from $\frac{1}{4}$ to 1 to 1 to 1, according to the solidity of rock and depth of cutting. In this cutting the phenomenon of "swallow-holes" was encountered. These are really large chambers charged with water, which, in rainy weather, is emitted in large quantities. In this part of the Cotswold Hills—for it is that ridge that this cutting and adjoining tunnel penetrates—numbers of



17.—DETAILS OF BRIDGE AT 21 MILES 50 CHAINS.

these cavernous holes and subterranean channels, which act as natural reservoirs, occur, and in cutting into these the outpouring of their contents, particularly in the winter time, caused considerable difficulty and necessitated special drainage of the cutting. In this cutting, owing to the rock formation, the form of structure known as a flying arch was adopted (Fig. 23).

Sodbury Tunnel, 4,435 yds. in length, commences at the termination of this cutting, and, as was before mentioned, passes through the Cotswold Hills, which attain an elevation at this point of over 600 ft. At its east end the tunnel traverses

FIG. 18.—A TYPICAL ACCOMMODATION BRIDGE.

the Forest Marble, and emerges at its west end in the Lower Lias formation, the strata dipping from the west to the east. The work was commenced from seven shafts, varying in depth from 80 ft. to 270 ft., six of which will be permanently retained.

A bottom heading was driven which was opened out at 13 different break-ups, the sections formed differing, as will be seen from the illustration, Fig. 7, from existing types, in being given a span of 27 ft. 6 ins. This is a foot wider than is usual, and more clearance is gained by its adoption.

The illustration shows that portion of the section designed with an invert, which was used for about three-quarters of a mile where the ground was in blue shale. The radius of curvature at the arch is 12 ft. 6 ins. at the crown, increasing to 15 ft. in the walls, diminishing downwards to 9 ft. 3 ins. A flatter form of invert was used

FIG. 19.—TYPE OF SHORT-SPAN OVERBRIDGE.

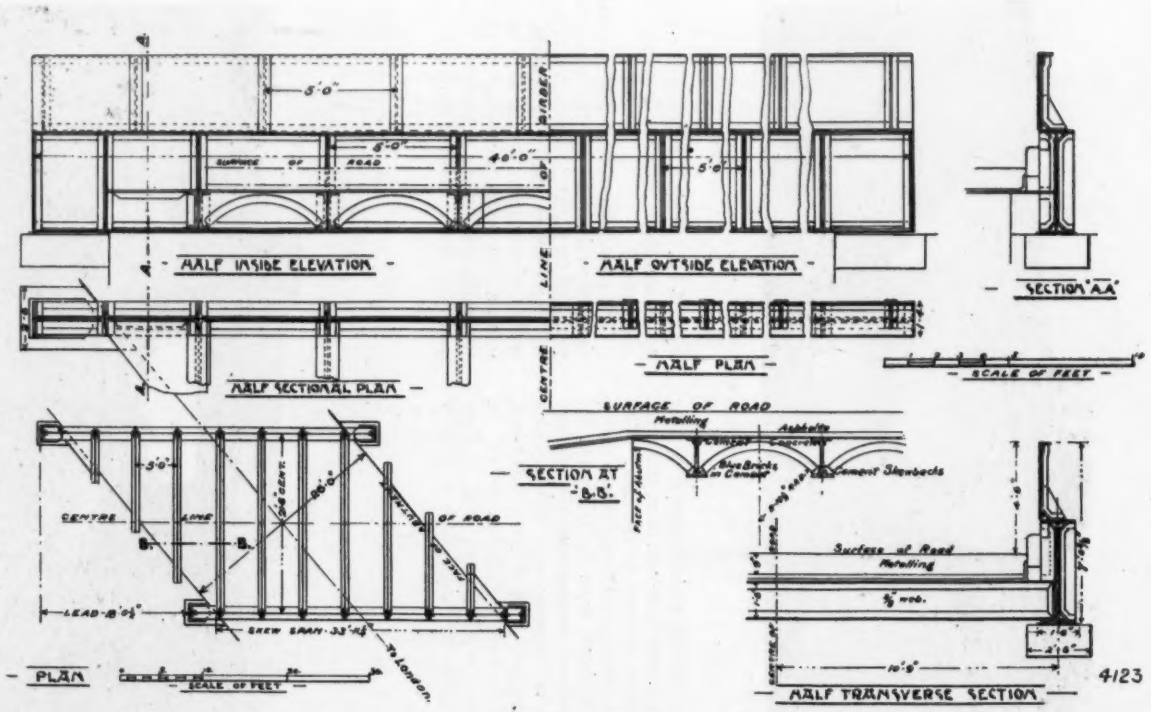


FIG. 20.—DETAIL OF TYPICAL OVERBRIDGE, WITH SUPERSTRUCTURE OF STEEL AND JACK ARCHES.

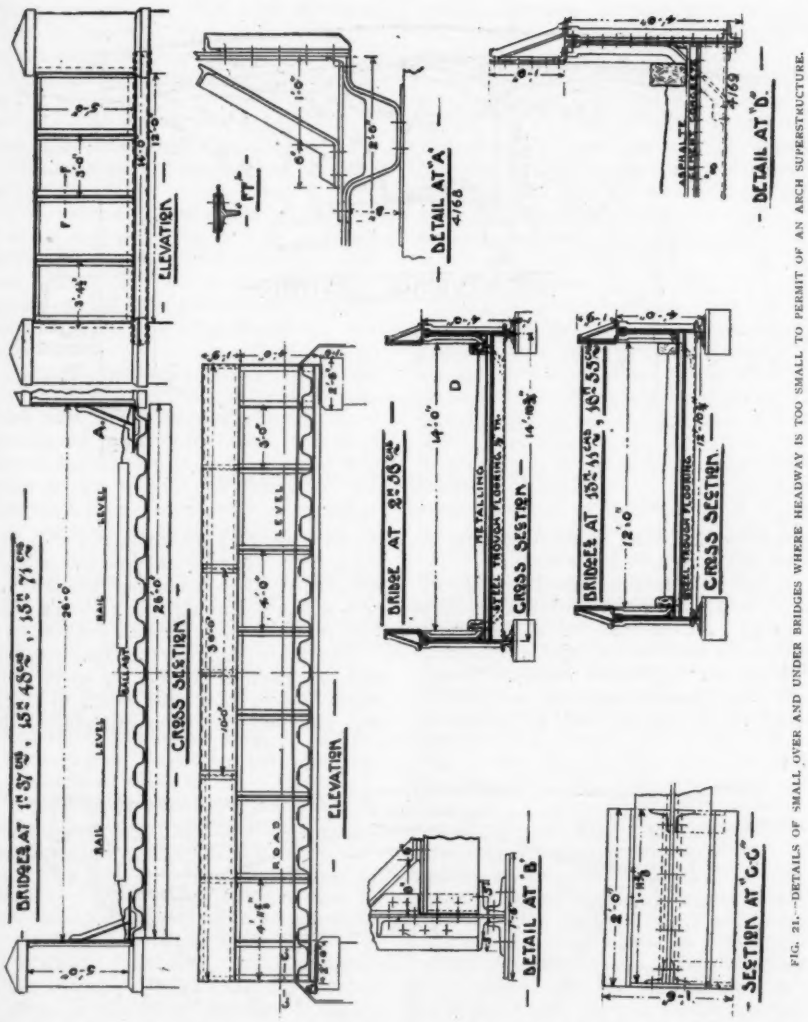


FIG. 21.—DETAILS OF SMALL OVER AND UNDER BRIDGES WHERE HEADWAY IS TOO SMALL TO PERMIT OF AN ARCH SUPERSTRUCTURE.

where the ground was better. The thickness of the arch-ring in this portion of the tunnel varies from 1 ft. 10½ ins. to 2 ft. 3 ins., that of the invert being 1 ft. 6 ins. For a certain length, where firm, hard rock was traversed, the arch was first built, and the walls at a later date, by the process of underpinning similar to the system generally adopted in the Alpine tunnels.

On the right hand side of Fig. 7 will be noticed a section for the ordinary type of wall where there is no invert, the thickness varying in this case from 1 ft. 6 ins. to 1 ft. 10½ ins.

Carried beneath the rail level is a 3-ft. culvert, which is capable of discharging 7,000,000 gallons every 24 hours, although it is not probable, except during the period

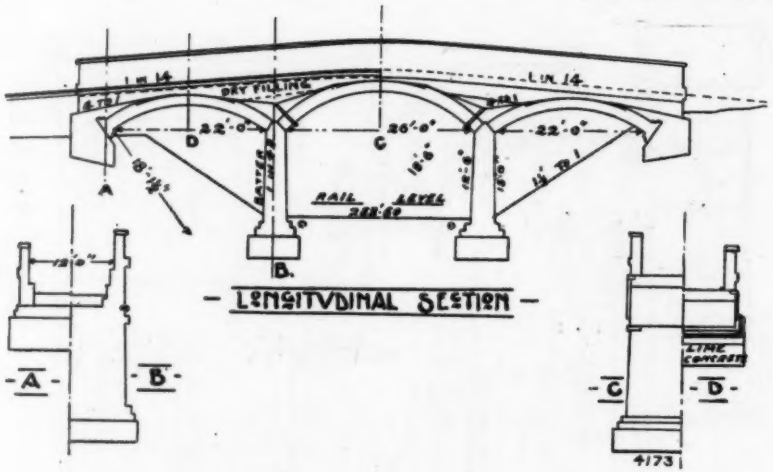


FIG. 22.—DETAILS OF TYPICAL ACCOMMODATION BRIDGE.

of heavy winter rains, that this quantity of water will have to be dealt with.

Local bricks have been used throughout, faced with Cattybrook and Staffordshire brindles. At the west end of the tunnel brickworks were erected capable of dealing with 100,000 red bricks weekly. These, with other needful material, were distributed to the tunnel end by means of trucks hauled up an inclined railway by the aid of a wire rope and powerful hauling machinery. The maximum gradient on this incline is 1 in 2½, and 50 loads of 20 tons could be taken up each working day.

The rate of progress varied considerably, and depended largely on the quantity of water that was met with, which in winter was sometimes very considerable. The

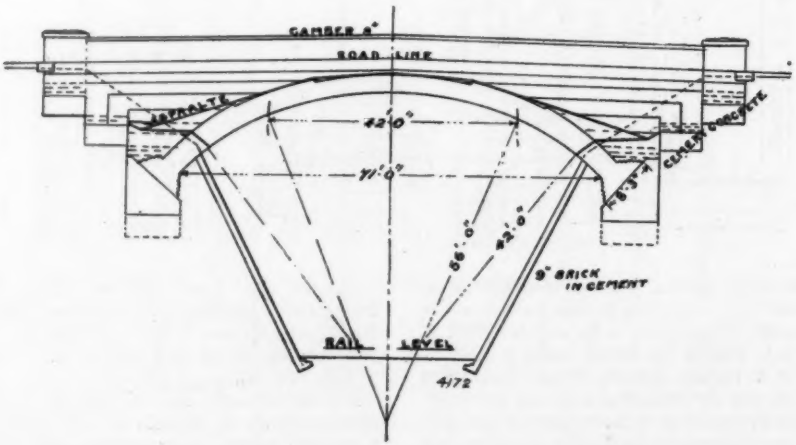


FIG. 23.—LONGITUDINAL SECTION OF FLYING ARCH.

average progress at each face, however, might be taken at from 4 to 8 yds. per month completed brickwork.

Fig. 8 shows the method of timbering for the full area of the tunnel in the heavy ground; and Fig. 9, reproduced from a flash-light photograph, also shows details of the timbering and the building in of the lining.

The western end of the tunnel, a view of which is given in Fig. 6, is immediately under the village of old Sodbury. The face is constructed of masonry, the stone being quarried from the adjacent cutting, which the line, on leaving the tunnel, now enters.

Sodbury cutting (Section 4), which traverses the lower lias, mountain limestone, and coal measures, extends for a distance of nearly three miles, and contains 1,800,000 cub. yds. of material, the depth at the tunnel end being 50 ft., rising to a maximum of 70 ft. at 1½ miles from the entrance, and dropping to 62 ft. another mile further west.

The limestone quarried from this cutting was used not only for the tunnel face, but for constructing some of the viaducts and bridges, as well as for ballast and road metalling. The gradient, which through the tunnel is falling 1 in 300, becomes, at ½-mile west, level for a distance of 24 chains, the object of this being to permit of the laying of locomotive water-troughs of the ordinary type.

In placing the site at this point, regard has been paid to the fact that water troughs should never be placed nearer to a home signal than from ½ to ¾ of a mile, as, in the event of this signal being against a train, the speed is not sufficient to cause the water to rise into the tanks.

Proceeding westward, the gradient becomes again 1 in 300, and at 21 mls. 30 chns. is Chipping Sodbury Station, the most important on the whole length. It is of the four-line type, and is situated about half a mile from the town of that name. The offices of the Resident Engineer are situated adjacent to the station.

At Wapley, a short distance beyond, the contractors established another large depôt covering an area of 12 acres, on which temporary dwelling huts, mission and reading rooms, engine and repair sheds, were erected.

In the neighbourhood of Westerleigh are three loops, known as the Westerleigh curves, by which the line is connected with the Midland system. The Great Western Railway has running powers over the Midland from Bristol to Gloucester, and one of the objects of these loops is to provide the emergency connection before mentioned, with the Severn Bridge, *viâ* Berkeley Road. Branch No. 1, which connects with the Midland down-line, is 1 ml. 34 chns. in length, and is on a falling gradient of 1 in 146·34; branch No. 2, which effects a junction with the Midland up-line, which it crosses by a bridge of 52 ft. sq. span, is 60 chns. in length, falling rather more sharply than branch No. 1; branch No. 3 is 40 chns. in length, and connects branch No. 1 and the new line in the direction of Bristol, and its object is to enable a train from the Midland railway to proceed direct in the direction of Bristol on the new line. Branch No. 1 provides similar facilities in the direction of London.

The line is now on embankment, and at 24 mls. 12 chns. crosses the Midland Railway, at an elevation of 37 ft. 6 ins., just south of Yate station, by a fine three-span masonry bridge with brick arches. Fig. 10 is a view of this structure, and Fig. 13 gives details of the centres erected for the middle span. To avoid interference with the Midland traffic, a temporary structure, containing some 10,000 cub. ft. of timber, was erected at a cost of over £1,000. Proceeding, the line crosses a mineral railway leading to a private colliery, after which a short cutting is entered, at the further end of which is situated (Section No. 5) another four-line station, viz. Coal-pit Heath, which place it serves together with the neighbouring colliery district. A large valley, through which flows the River Frome, is now crossed on an embankment 1½ mls. long and divided by two viaducts. The first of these spans, which crosses the main road to Bristol, was originally designed for eight spans, but five of these were replaced by embankment, owing to some old coal workings being discovered

when sinking the foundations. The coal seam was located, and it was found to reappear near the surface two miles away, after describing the arc of a circle. The foundations of the existing spans have been, for safety's sake, carried beneath the seam.

The second viaduct, spanning the River Frome, is 265 yds. in length, consisting of 11 spans of 58 ft., rising to a maximum height of 100 ft.

In the cutting through the slope of the hill on which the western end of the viaduct abuts, Pennant Rock was entered, and it is in this cutting, which is about half a mile in length, and rises to a height of 48 ft., that Winterbourne Station is situated.

The hill again makes a sharp descent, and the line enters on an embankment, divided by a five span viaduct 138 yds. in length and 84 ft. high, spanning the Bradley Brook (Fig. 15). Fig. 14 shows this viaduct under construction. The travelling gantry will also be noticed, by which materials were carried across the valley.

The line on leaving this bank, on which the long descent of 1 in 300 terminates, becomes level in Stoke Gifford cutting, which is three-quarters of a mile long. At Stoke Gifford, which is likely to become a very important place, an extensive area of ground was acquired, and a large marshalling yard for the goods and mineral traffic from South Wales has been formed. As has before been mentioned, the gradients of the direct line are very flat, while those of the old route reach 1 in 100. It is anticipated that, with these flat gradients and the aid of the more powerful locomotives now being constructed, trains of sixty loaded trucks will be hauled over the new line.

Near the 29th mile the line diverges, one loop running off to the left to Filton, terminating at 29 mls. 72 chns. at a junction with the existing line from Bristol to the Severn Tunnel; the other deviating to the right, joining up with the same line at 29 mls. 64 chns. a few hundred yards south of Patchway Station. Both loops are on embankment, the gradient remaining at 1 in 300.

There are something like 100 bridges on the line, most of which, however, fall under two or three types. It will suffice, therefore, if details are given of the more important of these. The largest arch is 76 ft. in span, with a rise of 16 ft. 9 ins.; the arch at the centre is 3 ft. in thickness, and at the springing 4 ft. 1½ ins., the pressure at the crown and at the springing 7½ tons per square foot. It is built with Staffordshire brindles and cement-mortar, and springs form a pennant rock foundation, the pressure on which is 4 tons per square foot.

Fig. 19 shows a convenient type of short span over-bridge where headway permits and has the advantage of being watertight.

In this case the skew span is 32 ft. 1⅛ ins., and the superstructure is formed by rolled steel joists 20 ins. in depth, weighing 83 lbs. to the foot, with a steel plate 12 ins. by ¾ in. riveted to the top and bottom flanges; the joists are 4 ft. 7 ins. apart centre to centre connected at 6 ft. intervals with ⅞-in. tie-rods. Jack-arches of Staffordshire blue brickwork 4½ ins. in cement are turned between the joists and filled in between the haunches and over the arch to the level of the top of the joist with cement concrete; ⅜-in. asphalte is spread over the concrete and 9 ins. of metalling above it. The total depth of the superstructure is 2 ft. 6½ ins.

Fig. 20 shows the details of a similar type of superstructure, where, however, the joists consist of a steel web 18 ins. deep by ⅜ in. thick, and two angle-irons top and bottom, 5 ins. by 3½ ins. by ½ in., resting in this case on two outside steel girders. The total depth of superstructure is 2 ft. 6⅜ ins., and the joists in this case are 5 ft. apart centre to centre.

Fig 21 shows details of typical small under and over accommodation bridges, where the headway is too small to permit of an arch superstructure.

In the case of the under-bridge the superstructure, which consists of a steel trough flooring, 8 ins. deep by ½ in. metal stretches across the 12-ft. span and rests directly on the two abutments; in a case of this kind cross sleepers are used for the purpose of distributing the load over

several troughs. This type of floor is used for spans up to 20 ft., in which case the troughing is 18 ins. deep and the metal $\frac{5}{8}$ in. thick. Above 20 or, at any rate, 25-ft. girders are employed, and in that case the flooring is laid at right angles to the direction of the permanent way, and a longitudinal timber is in consequence used.

Coming to the over-bridge, the span of which is 26 ft., it will be noted girders are used and a trough floor laid at right angles to the road. The flooring is filled in with cement concrete with a layer of asphalte $\frac{3}{4}$ in. thick over it.

The typical accommodation bridge used wherever headway would permit is shown at Figs. 18 and 22. It is of the three-arch type, with a centre span of 26 ft., and side spans of 22 ft. The arches are 1 ft. 10 ins. at the springing, and 1 ft. 6 ins. at the crown; and the piers, which are 3 ft. thick at the springing level, are battered 1 in 48. The label courses are generally in blue brick, with string courses and copings of ashlar.

A further example of a three-arch accommodation bridge is shown in Fig. 17, where the centre span is 57 ft. 6 ins. The details are clearly shown in the longitudinal and cross sections.

Fig. 23 shows a longitudinal section of one of the flying arches mentioned earlier in the article; while Figs. 12 and 11 show part longitudinal section and cross sections respectively, of the bridge carrying the line over the Midland Railway just south of Yate.

This bridge consists of three spans, the centre of which is 57 ft. 6 ins., and the two side spans 50 ft. each. The piers are 7 ft. thick at springing, and batter 1 in 30 on each side; the arches are elliptical in shape, 3 ft. $4\frac{1}{2}$ ins. throughout, and built entirely of brindle bricks.

Fig. 16 shows elevation, plan, and various sections of the Huckford Viaduct, the details of which are practically similar to those erected at Somerford and Winterbourne. In these three viaducts there were nineteen similar spans for which five centres did duty.

Finally, the headpiece of the article will serve to give an idea of a public road under-bridge, of which there are several examples.

The steelwork for the bridges was supplied by Messrs. Alexander Findlay & Co., Motherwell.

The permanent way is laid with $97\frac{1}{2}$ lb. bull-headed steel rails, 44 ft. 6 ins. in length, and were supplied by the Great Western Railway themselves. The sleepers, which are of Karri and Jarrah wood, have been laid 18 to the rail.

Parliamentary powers for making the line were obtained in the session of 1896 without the slighest opposition, and the contract let to Messrs. S. Pearson & Son, Ltd., shortly afterwards, on the schedule system, as time was an important object.

The scheme was promoted by Mr. James C. Inglis, M.Inst.C.E., the well-known engineer to the Great Western Company; while the operations are being supervised by Mr. W. W. Grierson, M.Inst.C.E., to whom the writer is indebted for the courtesy shown him when travelling over the line, and for the information, drawings, and photographs* necessary for the compilation of this article. Mr. Grierson's assistants in charge of the various sections are Mr. C. W. Scott, Mr. H. P. Maynard, Mr. Francis Brown; the work on behalf of the contractors being supervised by Mr. G. Hay, M.Inst.C.E., assisted by Messrs. Wilson, Gripper, Manton, Fraser, and Hyne.

* These were taken by Mr. W. H. Short, a member of the resident engineer's staff.

Lighting of Towns by Electricity.

By SYDNEY F. WALKER, M.I.Mech.E., M.I.E.E.

This popular exposition of the principles of town lighting by electricity has been undertaken at the request of not a few of our readers who are members of Town Councils, etc.—[THE EDITOR.]

THE development of few industries has been more rapid, more revolutionary in its character than that of Electric Lighting; yet, though Faraday's great discovery, upon which the enormous industry we are familiar with is built, was made in 1831, practically nothing was done till about 20 years ago. In 1874, when the present writer was Electrician to the Gramme's Magneto Electric Co., the then owners of the Gramme patents in this country, Electric Lighting was represented by two or three lighthouses and M. Gramme's factory itself. The Paris Exposition of 1878 gave a considerable fillip to electric lighting, the Avenue de l'Opera being lighted with Jablochkoff's candles, the first really practical electric lamp, which was soon after introduced on the Thames Embankment. Mr. John Hollingshead brought over from the Exposition an electric lighting plant on the Lontin system, which was used for an advertisement outside the theatre, and was afterwards tried without success at some of the stations on the Metropolitan Railway.

It is to the labours of Mr. Joseph Swan in this country in perfecting the incandescent lamp, as well as to those of Mr. Edison in America, and to the work of the late Dr. John Hopkinson and Mr. Gisbert Kapp in working out the law of the Dynamo, that we owe the possibility of the developments which have since taken place; while it is the historic discovery of M. Hippolyte Fontaine at Vienna that the dynamo was reversible, to which the great developments in the transmission of power by electricity are due.

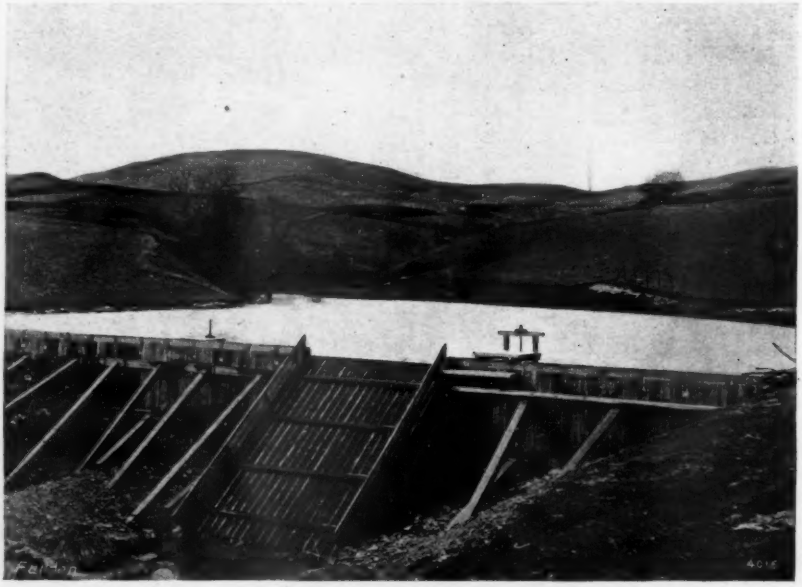
The earliest practical work in this country was done by the Brush Co. While we in this country were using one machine and sometimes two for each arc lamp, Mr. Brush showed us how to run 16, and up to 40 lamps from one dynamo. From that time electric lighting has never looked back, though it has passed through some very trying times, principally owing to the greed of company promoters. The incandescent lamp came on the market, though in a somewhat expensive and crude form, at about the same time; and from then onwards the development has been steady and continuous till at the present day in the United Kingdom there is no less than £26,000,000 capital employed in the generation of electric light. In 1882 came the first Electric Lighting Act, and the first Crystal Palace Electrical Exhibition; followed by the great Electric Lighting boom which led to no results beyond the waste of a good deal of the public's money. Some few towns even then, notably Taunton, did have the electric light; but there was nothing approaching what we understand by an Electrical Supply Station at the present day. In 1888 came a second Electric Lighting Act, which, while it was somewhat fairer to investors, also coincided with the successful working out of many of the practical details which go to make up the success of an undertaking of this kind. The incandescent lamp had taken a practical form in the interval, and many of its necessary accessories had been worked out; also large incandescent lamps up to 1,000 candle power had been made; the alternate current machine had again come to the front after one of its periodical eclipses; the transformer had become a practical apparatus; and Mr. Ferranti had worked a successful supply station at The Grosvenor Gallery in Bond Street, the company which had exploited it afterwards becoming the celebrated company which first startled the world under Mr. Ferranti's guidance with their 10,000 volt supply service between Deptford and the Grosvenor Gallery.

During the same period also, and before, another movement had been gradually gaining ground, viz., the ownership of gas, water, and other undertakings by municipal bodies; and as a consequence a large number of the Councils of our towns, and even a few villages, have taken advantage of the favourable provisions of the Electric Lighting Acts.

THE PROBLEM TO BE SOLVED.

Stated shortly, the problem to be solved consists in the conversion of the energy of water falling from a height above the sea level, or that set free by the combustion of coal, oil, or refuse, into light in such a form that it can be used for domestic and other purposes, just as gas, oil and candles are, and doing this by the aid of electric currents. Only a very few towns in the United Kingdom have utilised the energy of falling water for the purpose, because few towns have a natural supply of water-power in their neighbourhood; but on the Continent of Europe, and in America, in districts where coal is very dear, owing to the distance from the coal fields, water-power has been very largely used. Keswick, Worcester, Chagford, Ingleton, and Macroom (co. Cork) are the only places in this country where water-power has been adopted; and in the two former cases, it is only used as an auxiliary to the steam-power, and it is very doubtful if any saving has been effected, owing to the distance outside the town from which the water power has been derived.

Very few towns also have adopted either gas or oil as the source of power, though some have tried it, and it is also used in some cases as an auxiliary; but the use of the energy obtained by the combustion of refuse is likely to be adopted in a number of towns. Up to the present, Oldham, Shoreditch, are the best known instances, and the most successful. The average calorific value of town refuse is only about one-eighth that of the average steam coal; but as it is not only obtained for nothing but the refuse actually costs something to get rid of, even

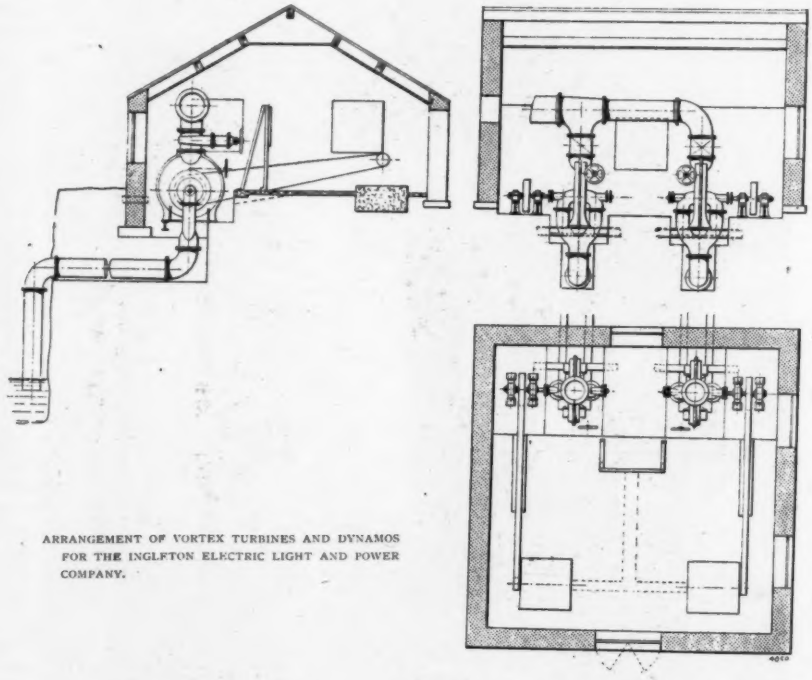


THE RESERVOIR AT KENDAL FROM WHICH WATER POWER IS DERIVED FOR TOWN LIGHTING.

THE PIPE LINE FOR WATER POWER STATION AT INGLETON.

POWER HOUSE AT INGLETON.

if it returns a portion of the cost of its disposal under other methods, in the form of steam, so that it can be usefully employed, a gain will result, besides the great gain of disposing of refuse in the very best sanitary manner. It is necessary, in burning refuse, to submit the whole of the material to a temperature of, at least, 1,500 degs. Fahr.; as some of the germs which harbour in refuse are very tenacious to life, and will succumb to no lower temperature; but this has been successfully accomplished in the latest forms of refuse destructors.



ARRANGEMENT OF VORTEX TURBINES AND DYNAMOS FOR THE INGLETON ELECTRIC LIGHT AND POWER COMPANY.

The development of electric lighting has been followed by the development of distribution of power by means of electric currents for the tramway services of towns, and also for industrial work. A striking instance of the utilisation of water power is that of Niagara, the engineer's dream of years; a portion of which is carried by means of conductors on poles to the city of Buffalo, 23 miles distant, where it is used for the tramway service, the lighting, and for running a large number of factories. The Niagara Power Co. are just increasing their plant, 50,000 h.p. was laid down originally, and more is being got ready.

Where water power is employed a dam of some kind is required across a river, or where it can be collected; and the water is led by a canal or pipes, on the level, to a spot where a certain portion of the fall of the river can be taken perpendicularly; and there the water is caused to work some form of water-wheel in its descent, the wheel, or turbine, as the quickly running water wheels are termed, turning one or more generators of electricity, the current being taken from the generators to the point at which it is to be consumed in the form of light, heat, or

INTERIOR OF THE POWER HOUSE AT INGLETON.

motive power. Where waterfalls exist Nature has made the dam.

Where gas or oil is used as the source of power, the gas, or the vapour of the oil, petroleum, is burnt in the cylinder of an engine specially constructed for the purpose; the heat being generated by the combustion, at the explosion causing a piston to move within the cylinder, which in its turn moves a crank shaft similar to that used in steam engines, which again causes one or more generators of electricity to revolve, the currents being taken from them to the point of consumption. There is every prospect that gas engines will play a large part in the future in the generation and distribution of light and power by electric currents. At present, notwithstanding the fact that the use of a gas engine does away with the necessity of a steam boiler, the gas engine has not found much favour with central-supply-station engineers. Its motion of revolution is not so steady as that of the steam-engine, while that of the steam engine itself is not sufficiently so in some cases; as where the generating station is situated in the centre of a town, and the vibrations caused by the uneven movements of its crankshaft are often transmitted to great distances, to the annoyance of dwellers in the houses to which the vibrations are transmitted, and the expense of the company or local authority who are running the supply station. Gas engines also have not been made of sufficient size, up till recently, for the requirements of large supply stations; and even now the largest gas engines only furnish 650 h.-p., while some of the steam engines in the supply stations of the large towns are able to furnish 2,000 h.-p. The winking in the lights, due to the manner in which the energy is delivered to the crank shaft, cannot always be suppressed.

The majority of the practice in the towns of the United Kingdom has therefore settled down to the consumption of coal under some form of steam boiler, the steam so generated being used to drive engines of various patterns; which in their turn drive the generators of electricity, the currents from them being taken out to the points of consumption, as with the water and gas power.

In delivering light to a consumer in the form in which he requires it, the electrical engineer has to convert and re-convert the energy which he receives from the water, oil, gas, or coal, several times. Thus, the energy of the motion of the falling water is converted into the energy of revolution of the waterwheel or turbine; the energy of the turbine into the electrical energy delivered by the dynamo generator, in the form of electric currents; the energy in the electric currents is carried by means of copper or aluminium conductors to the places where the light is required; and there it is again converted into the energy we know as heat, and light; as with gas, oil, or steam.

At every one of these conversions a charge is made for the conversion. At every step the engineer loses some of the energy with which he started, so far as the purpose to which it is to be finally applied is concerned; and every apparatus which takes part in the transmission or in the distribution of the energy also makes a charge for its services. Thus, when steam is employed, the boiler absorbs some of the heat delivered to it by the combustion of the coal; while the whole of the heat generated by the combustion of the coal does not get into the boiler. The boiler also distributes some of the heat delivered to it to surrounding bodies. The water engine, the gas engine, and the steam engine, all take toll of the energy delivered to them, for the purpose of overcoming the friction of their moving parts; and the engines which are actuated by heat, also distribute some of that which is delivered to them to surrounding bodies. The generators of electricity take toll of the energy converted by them, for the purposes of overcoming their friction, and for the provision of the magnetism without which they would not be able to generate electric currents. The cables through which the currents pass on their way to the lamps also take toll of them, a portion of the electric energy passing through the cables being converted into heat. The lamp itself takes, perhaps, the heaviest toll of all, where it is of the

incandescent form; only 5 per cent. of the energy of the current which is delivered to the lamp filament appearing as light. It is the office of the engineer to reduce these charges, all of them, to the lowest possible figures; and the greater his success in so doing, the greater will be the profit on the commercial transaction in which he is engaged, that of supplying electric light.

THE BOILER.

The steam boiler. It takes various forms, all designed to ensure that the largest proportion of heat generated that is possible shall be passed into the water that is to be converted into steam.

In the simplest form the boiler shell has one or two large tubes running throughout its length; and the heated gases which are formed by the combustion of the coal are led through these tubes, the water filling up the remainder of the space. When the boiler is short and of comparatively large diameter, and has only one large interior tube, it is called a Cornish boiler from the fact that this type was a very favourite one in Cornwall; when the boiler is long and has a small diameter, and has two tubes, it is known as a Lancashire boiler. The object in each case is to expose as much heating-surface to the water as possible. In later forms of Lancashire boilers, those made by Messrs. Galloway, Adamson, and other firms, the tubes are divided up by connecting pieces through which the heated gases also travel, again increasing the heating surface and at the same time the mechanical strength of the boiler. A further development of the same idea is taken in the marine boiler, in which the boiler is divided up by a large number of small tubes through which the heated gases pass on their way to the chimney, the water occupying the space around them; and the idea has again been extended by providing tubes for the water to travel in, and allowing the flames and heated gases to play all round them; this is the well-known water-tube boiler, of which so many are now used. The furnace in which the coal burns sometimes forms part of the boiler shell, and sometimes is made separate. In either case the back of the furnace is connected with the portion of the boiler provided for the occupation of the heated gases.

Heat is lost, or uselessly expended in the boiler by imperfect combustion of the coal, by an insufficient supply of air, or by a too great supply, and by the heated gases being allowed to escape to the chimney at a very high temperature, without having given up all the heat which has been delivered to them, by the combustion of the coal, to the water or the steam.

Another source of waste, or rather want of economy in the early days of the use of steam was the fact that only very low pressures of steam were employed. The largest portion of the heat which is required for raising steam is taken up in the act of conversion from water at boiling point, 212° Fahr., to steam at the same temperature; a comparatively small proportion further is required to raise the pressure lb. by lb.; and so one of the economies of modern engineering, which is practised in all central supply stations, is to use steam pressures as high as possible. In marine engines pressures as high as 250 lbs. per square inch are used, and in town central electrical station work pressures of 150 lbs. are common.

Two other sources of economy have also been developed in connection with the raising of steam, viz.:—the drying or superheating the steam before it enters the engine, and heating the water which is used to feed the boiler with the heat which is left in the gases from the furnace after they have left the boiler. The superheater consists of a nest or length of pipes through which the steam is made to pass, on its way from the boiler to the engine, and around which the gases from the furnace are allowed to play. The result is to raise the temperature of the steam, so that there will be less condensation of steam in the engine cylinders at each stroke, this being one of the sources of waste. The cylinder takes toll of the heat delivered to it by the steam at each stroke, to raise its own temperature to that of the entering steam; superheating the steam gives it some extra heat which it can

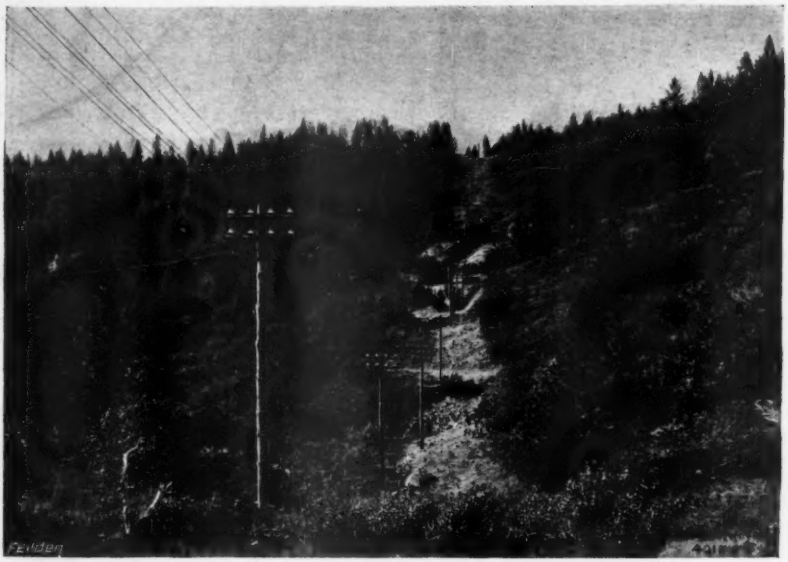
part with and so avoid lowering the actual steam temperature; it also dries the steam, that is, it converts the watery vapour which is carried over from the boiler with the steam, and which is not steam, but is ready to deposit as water on the slightest fall of temperature, into steam.

The economiser is also a nest of pipes round which the gases from the furnace play as they come from the furnace towards the chimney, and through which the water from which the boilers are supplied is caused to pass, so that—instead of entering the boiler at a much lower temperature than the water and steam already in the boiler, and so lowering their temperature—it enters at a temperature not far below that of the water already in the boiler. Each pound of water, which is heated to a temperature of 1 deg. Fahr. above the ordinary temperature of the surrounding atmosphere absorbs one heat unit; and it absorbs one heat unit for every degree that its temperature is raised; so that every degree of temperature imparted to the feed-water from the heat of the gases, which would otherwise be wasted, is so much gained, or saved.

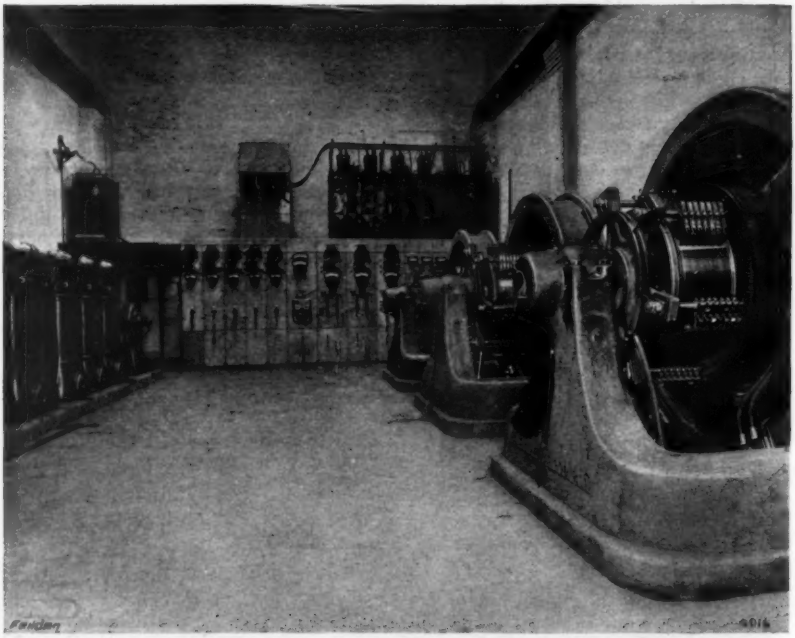
MECHANICAL STOKERS.

Another source of economy is the mechanical stoker. In place of the coal being thrown into the furnace by hand, each time that it is wanted, it is thrown, dropped, or pushed in automatically at regular intervals, by an apparatus provided for the purpose. A hopper surmounts the furnace doors, in all the various types, and at certain times a valve, or door at the bottom of the hopper, or of a shoot attached to it, opens; and at the same time a certain motion is given to the coal, causing it to descend on to the bars below. In some forms the bars themselves are also given a certain motion at each feed, tending to shake the fuel towards the back of the furnace.

The mechanical stoker economises in



SUPPLY WIRES GOING ACROSS COUNTRY IN CALIFORNIA FROM POWER HOUSE.



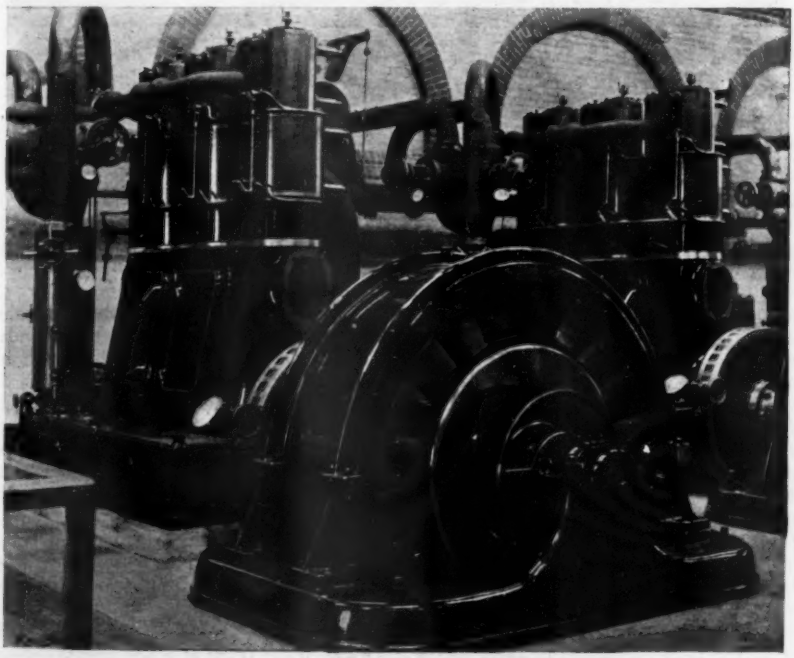
AN EXAMPLE OF A CONTINUOUS-CURRENT GENERATING STATION, U.S.A.

two ways, it economises heat by avoiding the necessity for opening the furnace doors, and it allows inferior coal to be burnt with success, which would not be possible with hand firing. In electrical supply stations it is usual to supplement the mechanical stoker, by apparatus for bringing the coal from the barge, or the truck, to the coal stores, and from there to the hoppers, and for taking away the ashes.

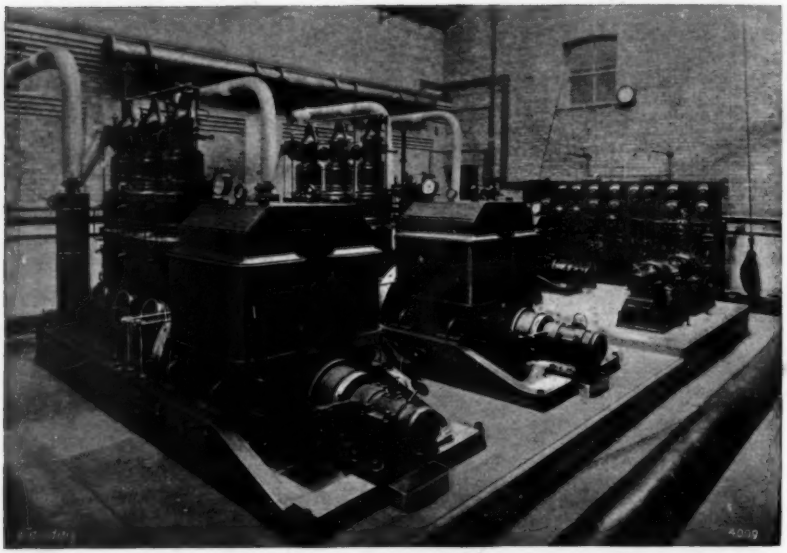
THE STEAM ENGINE.

The steam engines now commonly used in town electric supply stations are either compound, or triple expansion; that is to say, they have either two cylinders, through which the steam passes in succession, or three. There may be two or three sets of cylinders, each set taking the steam in succession; the engines also may be what are now termed quickly revolving, or slowly revolving. The quickly revolving, or high speed, as they were termed until a few years back, run at from 300 to 500 revolutions per minute, and are coupled mechanically directly to the generator dynamos they are to drive; the slowly revolving or slow-speed engines, as they are often called even at the present day, run at from 80 to 140 revolutions per minute; and they sometimes drive the electric generators by means of belts or ropes, nearly always by ropes, belts having the objectionable feature that they make so very much noise; but in later forms the moving part of the dynamo is made to form part of the fly-wheel of the engine, revolving with it. The quickly revolving engines are much smaller than the slowly revolving for the same work, and usually cost less. The term high-speed engine has been shown to be a misnomer, the supposition being that the so-called high-speed engine travelled faster than the so-called slow-speed engine; but this is not so, though the revolutions are less,

the speed of the pistons and other moving parts is about the same, while the momentum of the moving parts of the slowly revolving engines must be much greater. Slow-running engines are preferred in some parts, notably in Lancashire, where mill engines of that type have been in use for so long with such great success. In the great majority of towns, however, quickly revolving engines directly coupled to the generators, and slowly revolving engines built round the dynamos, and sometimes forming part of the generators, are rapidly becoming the rule. The combined plant takes up less space, itself an important matter in some cases where the station is situated in the middle of a town; it is more efficient than a belt- or rope-driven combination; it makes a smaller charge for conversion; and the direct connection eliminates one great source of weakness, the possibility of the belt or rope breaking. The quickly revolving engines also set up less vibration in the foundations and the building than the slow-running engines; this matter also being of considerable importance in towns. The quickly revolving engines are now usually made with two or more cranks in one line; the different cranks delivering the energy of their respective sets of cylinders to the crank-shaft. A favourite plan also with quickly revolving engines, is to have the high and low pressure cylinders vertically above each other; the steam entering the high-pressure cylinder at the top and working its way down to the exhaust of the low-pressure cylinder at the bottom; the piston-rods being in one vertical line, and the pistons parallel with each other also, one above the other.



257-K.W. ALTERNATOR AT THE CROYDON LIGHTING STATION.



VIEW OF THE GENERATING STATION AT HULL.

The object of the successive cylinders with compound and triple-expansion engines is to obtain the full benefit of the economy realised by the increased pressure to which the steam is raised. If steam at 150 lbs. or thereabouts is used merely in the place of steam at say 50 lbs. pressure, and in one cylinder, a certain economy is effected; because a smaller quantity of steam will perform a certain work when the steam is at higher pressure; but the full economy is not reached in the same manner as it is when the successive expansions take place in successive cylinders. In order that the smallest possible quantity of steam shall perform a certain work, it must be allowed to expand right down to atmospheric pressure, or as near that as possible; and this cannot be conveniently done in one cylinder, on account of the wide range of temperature. As the pressure of the steam rises, the temperature rises also; and the metals of which the cylinders are composed follow the changes of temperature to a certain extent; the temperature being high when steam is first admitted, and falling as the pressure lowers; hence the condensation before referred to, and the consequent loss of steam which has to be made up at the boiler, and which causes other troubles. Most steam engines which are used in central stations at the present day also make use of condensers for the purpose of securing a further economy. The steam which is left in the cylinders at the end of the stroke of the piston has to be forced out by the piston on its return stroke; and a portion of the energy of the entering steam is consumed in overcoming this back pressure, as it is termed. If the steam which is left in the cylinder can be instantly converted back into water, its back pressure will be extinguished, and it will be extinguished in proportion as this is accomplished. This is done by passing the exhaust steam, the steam which has done its work, into and through a condenser of some form; where other water, maintained at a low temperature, is caused to take up some of the heat of the steam and so convert it back into water;

while a pump withdraws it and delivers it into the hot well from which the feed water for the boiler is taken. Condensing is economical in those cases where a supply of water for cooling purpose is obtainable at a cheap rate, or where the condensing water can be cooled at small cost and used over again, otherwise it is not. It is a question of the cost of the condensing water and of running the condensing apparatus against the saving in coal effected by condensing.

THE ELECTRIC GENERATORS.

Next comes the Electric Generator, or the Dynamo, as it is often called, which consists usually of a mass of iron and copper so arranged that a very powerful magnetic field is formed within a closed space, in which a number of copper conductors are caused to revolve, giving rise to electric pressures in the revolving conductors, which are delivered to the conductors leading to the lamps, producing currents in them. The generator may be of the continuous-current, or alternate-current type; and again, if of the alternate-current type, it may furnish one, two, or three currents, all independent of each other. Continuous-current machines consist of a massive framework of iron, enclosing a cylindrical hollow chamber, called the polar space, and having coils of wire wound on some portion of the iron framework, for the purpose of carrying the currents which make the whole apparatus a huge magnet, within the magnetic force concentrated within the polar space. Within this space what is termed the armature is carried. It consists of other wire coils carried on a cylinder made up of thin iron plates strung on a steel spindle; and the wire coils are connected to the section of another cylinder made up of a number of sections of copper, separated by plates of mica, and called the commutator. Blocks of carbon, strips, or bundles of copper-gauze rest on the sections of the commutator, being held against it by apparatus carried by the frame of the machine. The armature as a whole—iron cylinder, wire coils, copper and mica commutator, all carried on the steel shaft—revolves within the polar space; and, as it revolves, generates the currents which are delivered to the cables to be taken to the lamps. In the latest forms of continuous-current machines which are used in large stations, the generators are constructed very much like alternate-current generators; that is to say, with several field magnets instead of only one pair as in the smaller machines. The reason is, it is not possible to construct machines above a certain output without either making them very unwieldy, and difficult to arrange for the proper collection of the currents, or making them with several pairs of poles, and the same number of magnetic fields. By dividing up the work in this way the difficulty involved in the size, large currents to be dealt with and other matters, have been successfully overcome.

(To be concluded.)

Sydney F. Walker

New Machinery. Appliances. Structures. & Processes.

Plate-bending Rolls for Chatham Dockyard.

Our supplement plate this month illustrates a powerful set of plate-bending rolls of a type specially adapted for long and heavy plates, constructed by Messrs. Craig & Donald, Ltd., Johnstone. This machine, which occupies a space of 25 ft. in height and about 40 ft. in length, has all the rollers of forged steel, and both the top roller and the two bottom rollers are stayed effectively by means of three sets of anti-friction boilers. The brackets, which hold the stay-rollers for bottom rolls, rest on two massive built-steel girders, and the top roller is stayed in a similar way.

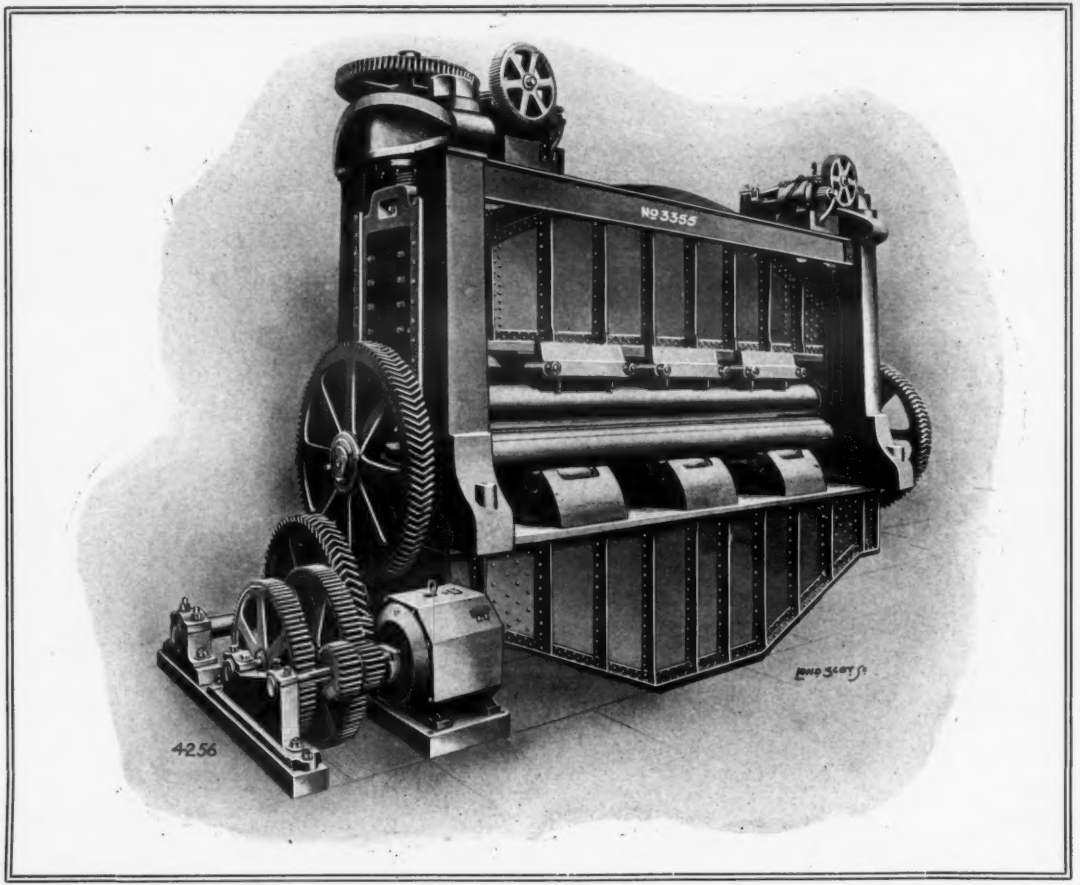
The housings, which carry the rollers and top girder, rest on the ends of the under girders, and the tops of the housings are held down by massive forged bolts, which pass through the cross-heads and housings to the underside of the girders. The whole of the gearing is of steel, and very strong. The illustration shows the drive by direct application of electric motor, the motor being of the series wound reversing type. The top gear, for raising and lowering the top roller, etc., is actuated by a reversing motor at each end. This machine has two varieties of speeds to suit the heavier and lighter plates. The illustration is from a photograph of a machine made by Messrs. Craig & Donald for H.M. Dockyard at Chatham, and designed to bend nickel steel plates, when cold, up to 25 ft. wide by 2 ins. thickness.

The Largest Single-Span Stone Bridge, Luxemburg.

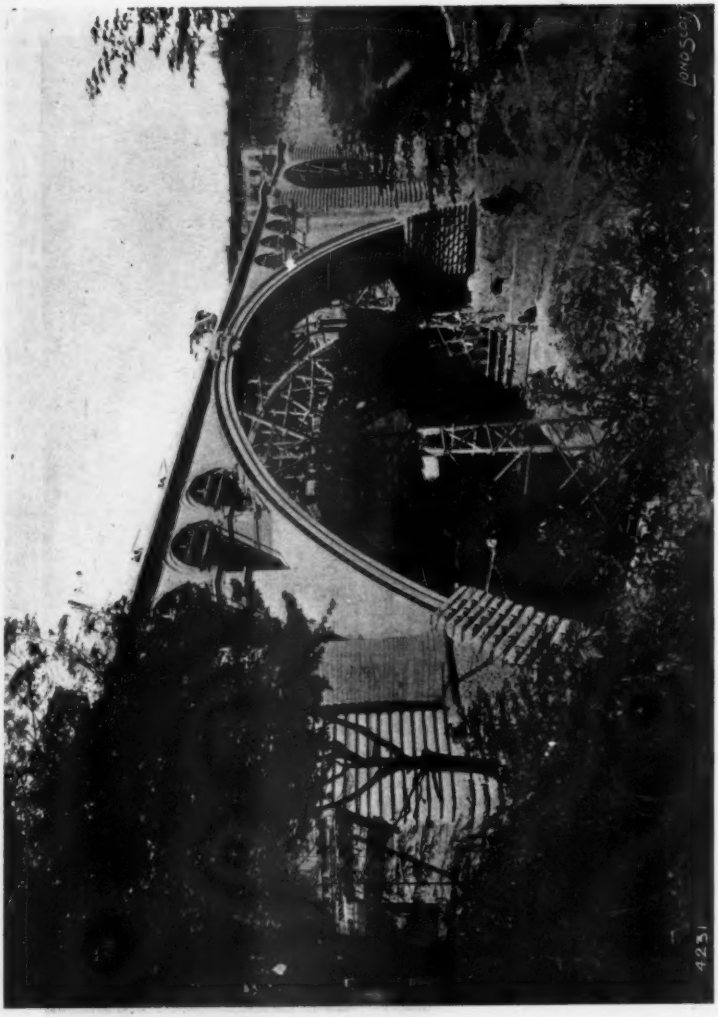
The Grand Duchy of Luxemburg, now an independent principality thanks to the Treaty of London in 1867, although having passed successively under the domination of several European powers, is no larger than an average English county; but it is remarkable in more than one respect. It possesses a thermal spring which is more highly mineralised than that of any other on the Continent, and probably in the whole world. Its iron ore deposits, which were revealed by the construction of the first railway in 1859, if not actually richer in iron than those in the adjacent regions of France, Belgium and Germany, are more valuable because containing a larger proportion of limestone in intimate combination, which greatly facilitates their smelting. It has been predicted that Luxemburg will eventually become the centre of the basic steel production in Europe. Now the little State holds the record for possessing the largest single-span stone bridge in the world, surpassing by more than 40 ft. that of the bridge thrown over the Adda, Italy, in 1377, but destroyed in 1416 after a civil war, while the span of the Chester bridge is 77 ft. less than that at Luxemburg.

When the Wilhelm-Luxemburg railway was made, traversing the country from north to south, the State formed part of the Germanic Confederation; and, owing to strategic considerations, the station serving the capital was placed about a mile from its centre. Luxemburg City, formerly the stronghold of Europe, is built

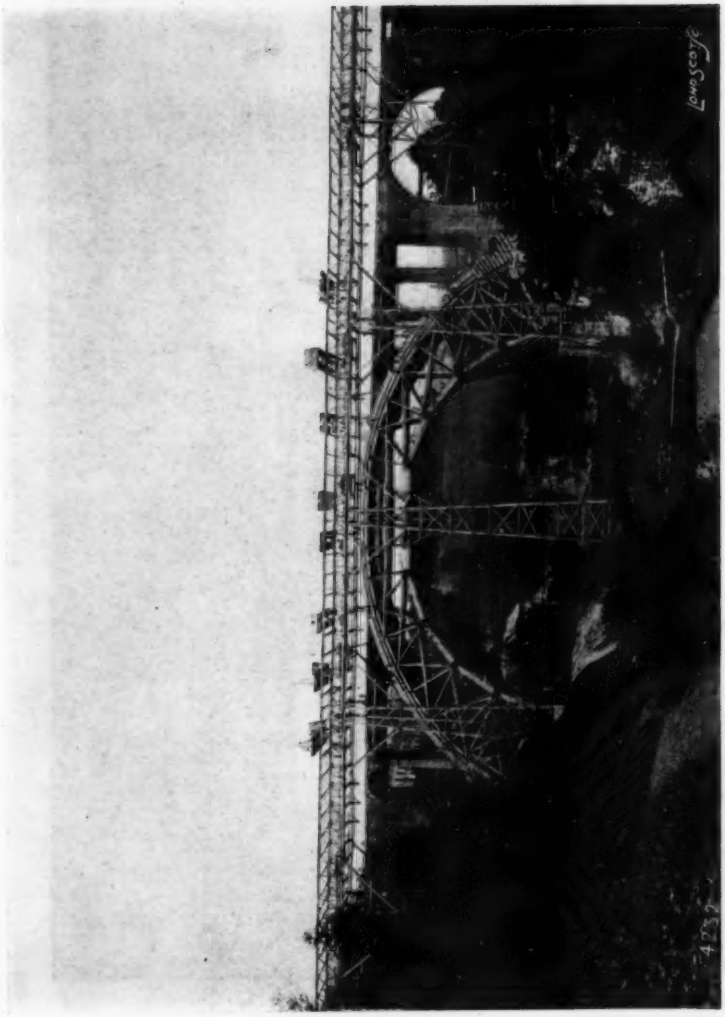
SUP



SET OF PLATE BINDING ROLLS, CONSTRUCTED FOR H.M. DOCKYARD AT CHATHAM BY MESSRS. CRAIG & DONALD, Ltd., JOHNSTONE, N.B.



THE LUXEMBURG BRIDGE.



THE LUXEMBURG BRIDGE: VIEW SHOWING THE CENTERING.

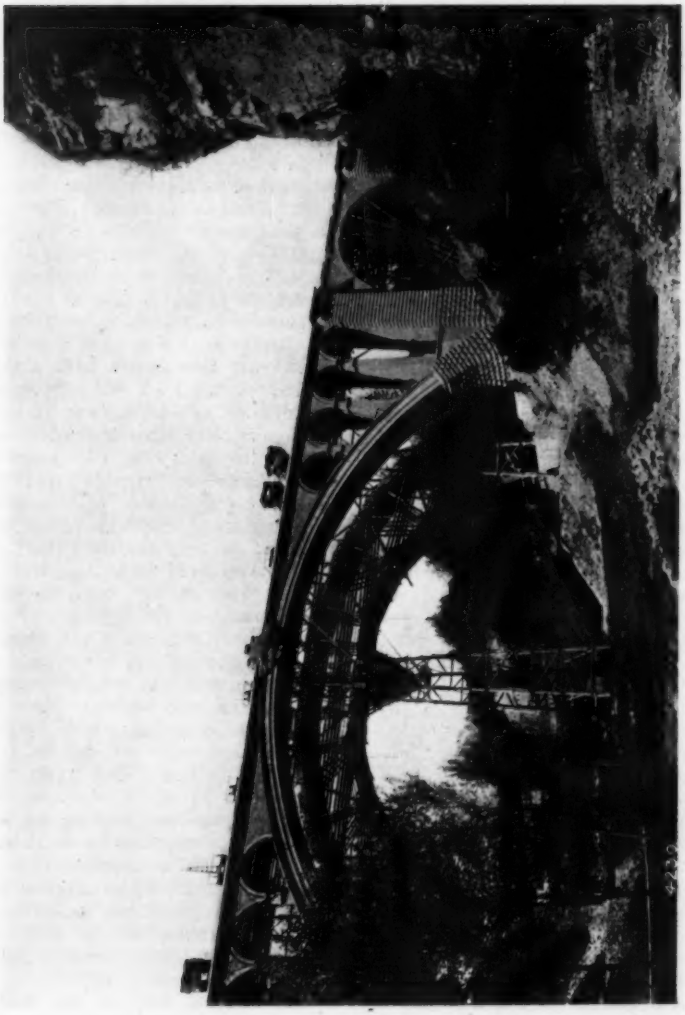
on a plateau constituted of sandstone, surrounded on three sides by deep valleys, having towards the city almost vertical sides; and the station is on another plateau, the only communication between the two being afforded by a stone viaduct, 350 m. (382 yds.) long, highly picturesque, but excessively inconvenient owing to its slight width, 8 m. (26 ft.). As a tramway is laid on part of this width, it may be imagined that, on market days especially, traffic becomes very difficult. So early as 1875 projects were made for affording additional communication; but it was only decided quite recently to throw a second viaduct over the Petrus valley for connecting the city, that was formerly pent up within the fortifications, with the new district now springing up round the station. An iron bridge would have been cheaper and perhaps more easily constructed than one of stone; but, on account of the rocky situation, a stone viaduct was considered better to harmonise with the surroundings, while perhaps also affording facility and economy in maintenance.

The definite design was entrusted to M. Séjourné, Ingénieur-en-Chef des Ponts et Chaussées of France, Chief Engineer of the Paris-Lyon-Méditerranée Railway, and Professor of the École des Ponts et Chaussées, Paris, who had already carried out several large single-span stone bridges, especially those of Lavaur, 61·5 m. (201¾ ft.), and Antoinette, 50 m. (164 ft.). In the Luxemburg bridge, three different views of which are shown by the accompanying photo reproductions, the elliptic arch is carried down to a solid foundation below ground level, so that there are no piers to the main arch. The span at the springing of the foundations is 84·65 m., or nearly 277 ft.; and that measured at the top of the arch abutments, well above ground level, 72 m. (236 ft.). The total height from the bed of the Petrus to the soffit of the keystone is 42 m., or nearly 138 ft.; and the rise of the arch above abutments, 16·2 m. (53 ft.). The radius of the greatest curve at the underside of the crown is 53 m. (174 ft.); and the thickness of the arch at this point 1·44 m. (4 ft. 9 in.), while the thickness of the arch where it springs from the abutments is 2·16 m. (7 ft.).

In reality, the bridge consists of two distinct halves, connected only at the top by a platform made of what is called armoured concrete, or concrete strengthened by the intercalation of iron ties. It is thus that the width of the intrados at the crown is 5·53 m. (18 ft.); that at the top of the abutments 6·12 m. (20 ft.); and that at the base of the foundations 9·22 m. (30 ft. 2 ins.), leaving, between the two longitudinal halves, a free space of 5·92 m. (19 ft. 4 ins.) at the crown. The span of the semicircular spandrel-arches, four at either side of the main arch, is 5·4 m. (17 ft. 8 ins.), and their thickness at the keystone 0·54 m. (1 ft. 9 ins.), while the thickness of their piers at the springing of these arches is 1·08 m. (3 ft. 6 ins.). The semicircular side arches have a span of 21·6 m. (70 ft. 9 ins.), with a thickness, at the keystone, of 0·88 m. (2 ft. 10 ins.).

There is more than one advantage in forming the bridge in two longitudinal halves, both as regards quantity of materials and facility of construction. The quantity of timber required for the centering is only one-third that which would be required by a single arch 16 m. (52½ ft.) wide at the crown, because the second arch, on the further side of the space between the two, is now being built with the centering that has already served for the first, and was simply pushed forward into its new position. As a matter of fact, the centering, which weighs 300 tons, required only 380 cub. m. (13,420 cub. ft.) of timber. Then again there is a reduction of about one-third in the quantity of masonry, because one-third of the materials required for a 16-m. arch suffices to build a complete arch 5½ m. wide. Moreover, by proceeding in this manner it was found easy to build a complete arch, forming half the bridge longitudinally, in a single season, a matter of no little importance.

The carrying out of the work was entrusted to the well-known firm of contractors, MM. Fougerolle Frères, of Paris, M. Séjourné being retained as engineer-in-chief, and M. Fonck acting as resident engineer. The temporary bridge, that



ANOTHER VIEW OF THE LUXEMBURG BRIDGE.

permitted of putting up the main centering and bringing up materials for building the arch over its whole extent, one longitudinal half after the other, consists of seven trestle piers of varying heights, corresponding with the section of the valley, spaced 30 m. (98½ ft.) apart, and carrying a timber truss 3 m. (10 ft.) deep. This temporary bridge, 7 m. (23 ft.) wide, was constructed exactly over the site of the first large arch, carrying on its bottom member a pair of rails, stocked with Decauville trucks for bringing up the materials, and on its upper member a line of way 7 m. (23 ft.) wide, on which run the travelling cranes that lower the materials to the exact point required. Notwithstanding its length of more than 170 m. (557¾ ft.) and the great height of the piers required by the depth of the valley, this bridge was made with only 320 cu. m. (11,301 cub. ft.) of timber, and cost no more than 25,000 fr. (£1,000), or less than 1s. per cub. yd. of the masonry, which measures 20,000 cub. m. (706,331 cub. ft.)

The timbers of the main centering, very light and original, also designed by M. Séjourné, are put together, and also stayed (as may be seen in one of the photographs), by wire ropes; and the structure is carried by foot walls 60 m. (197 ft.) apart. After the first arch was completed, the centering was shifted bodily on the two walls, a distance of 11·25 m. (37 ft.), so that it was brought immediately over the site of the second arch, this operation having been effected in 25 hours last January. For accomplishing this it was necessary to make the timber truss bear on the masonry of the first large arch, after which the upper part of the trestle piers was taken down so far as the soffit of the arch, when the centering was shifted laterally, the lower part of the central pier being carried by a truck. The other piers were then re-erected in their new positions for receiving the temporary bridge, brought exactly over the site of second arch.

The main arch was built in three rings, each divided into several lengths or sections, according to a method devised by M. Séjourné, and described by him in "Les Annales des Ponts et Chaussées," of October, 1886. He has observed that, whatever precautions may be taken, the centering inevitably settles, thus causing cracks and fissures at every point where the keying is effected. Accordingly, at each of these points an opening is left in the ring, and these openings are keyed when the rest of the ring is finished. Not only is all fissuring prevented by this method of proceeding, but it also has the great advantage of permitting the construction of the arch to proceed simultaneously at as many points as may be found convenient. In the Luxemburg bridge the building proceeded simultaneously at ten different places in each of the three rings, making altogether 59 keying operations; and in this manner each ring was completed in from 8 to 10 days.

The stone, quarried in the neighbourhood, has a resistance to crushing strain varying from 1,200 to 1,500 kilograms per sq. cm. (mean 19,200 lbs. per sq. in.); and the various mortars were mixed mechanically in steam-driven mills with edge-runners of stipulated weight. Vicat No. 1 artificial cement is used exclusively for the main arch; lime from Teil, in France, for the abutments, and lime from Luxemburg in the remainder of the work.

The first half of the main arch was keyed on 24th July, 1901; and the centering struck on the 26th October following, when the settlement at the crown was found to be only 6 mm. (not ¼ in.). The second large arch was keyed at the beginning of June this year; and its centering will be struck in September.

This unique bridge, the utility of which is unquestionable, while its artistic effect is evident from the photographic views, affords subject for heartily congratulating its designer, and also the enterprising Luxemburg government.

Electrical Installation at Linwood Paper Mills.

THE following gives a description and particulars of an electrical power installation which has been running upwards of one year at the Linwood Paper Mills, Linwood, Renfrewshire, N.B., the property of Messrs. R. & W. Watson. This installation is of special interest, inasmuch as the entire steam-generating and motor plant are of the most economical type, and it is perhaps the only paper-mill in the country where the various operations in connection with this manufacture are carried out by means of motor drives.

In common with the almost universal practice in paper mills, Messrs. Watson had, prior to the change referred to, a large number of engines scattered throughout the several departments, with the usual ramification of steam piping and shafting required for transmission, entailing losses by radiation, condensation, and friction, which, in many works, are of a very serious nature. Along with these disadvantages, there was the difficulty of maintaining the scattered engines, with their connections, in order; particularly where the requirements render continuous running necessary, and when the only opportunities for repairs and packing, etc., occur at week-ends.

The regulation of speeds is of primary importance in paper manufacture; and, to obtain this end, the old system of working involved, at all times, the closest attention on the part of the attendants, and frequently with only partial success. In this respect it was decided that, even although the new electrical plant should not turn out to be more economical in respect of fuel than the one that has been replaced, the greater facilities offered for regulation of speed and general manipulation of the paper materials in the different stages would amply justify the change from mechanical to electrical driving. Economy in fuel and labour, however, are also secured to a highly satisfactory extent, inasmuch as results, carefully ascertained, which are tabulated at the end of this description, will fully show.

The installation consists at present of two units, but, when completed, there will be four, each being equal to a load of 450 i.h.p.

We shall begin by describing, firstly, the steam generating plant, comprising boilers, economisers, feed-water heaters, pumping and filtering plant, etc.; secondly, the generating plant; and, finally, the motors, and their various applications.

The boilers, which are two in number, are by Messrs. Babcock & Wilcox, each having 3,580 sq. ft. of heating surface, and constructed for a daily working pressure of 260 lbs. per square inch, both having been tested hydraulically to a pressure of 375 lbs. per square inch. The furnaces are fitted with Messrs. Babcock & Wilcox's patent chain grate stokers, and the boilers are also fitted with this firm's patent superheaters. Each superheater is made up of 64 tubes, having a heating surface of 460 sq. ft., and the steam in the superheater main has a total temperature of about 500 degs., Fahr. The exhaust steam feed-water heater contains 316 sq. ft. of heating surface, and is capable of withstanding a steam pressure of 260 lbs. per sq. in. The shell of the heater is made of wrought steel, and there are 90 solid drawn-brass tubes, each 8 ft. 10 ins. long. The heater, which is capable of dealing with 22,000 lbs. of water, takes at present the exhaust steam from the air and feed-pump engines, the resulting temperature in the feed-water being about 160 degs.

The economisers, which are by Messrs. Lowcock, Ltd., Shrewsbury, are of novel design, consisting of eight benches or blocks of tubes, there being 20 pipes in each block. The economiser completely fills the lateral space of the flue, there being no side passages or deflectors. There are, however, spaces between each block which can be got into through convenient port-openings in the building, for cleaning and inspection purposes. In addition to the usual scraper gear, the arrangement of the building allows of the tubes being brushed with steam jets as required. The water enters the economiser

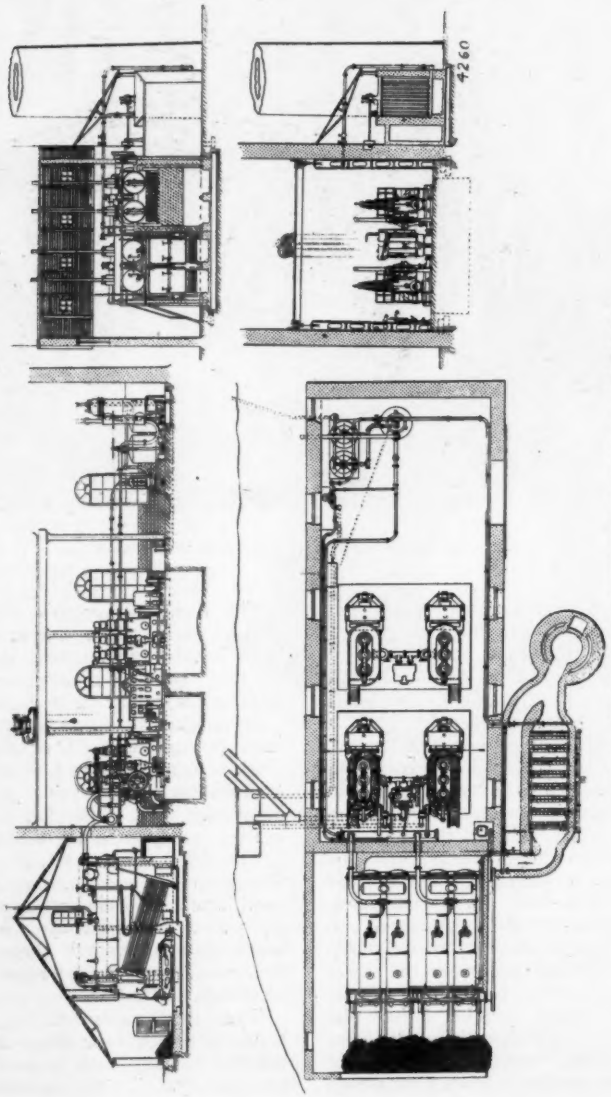


FIG. 1.—ARRANGEMENT OF POWER STATION AT LINWOOD PAPER MILLS.

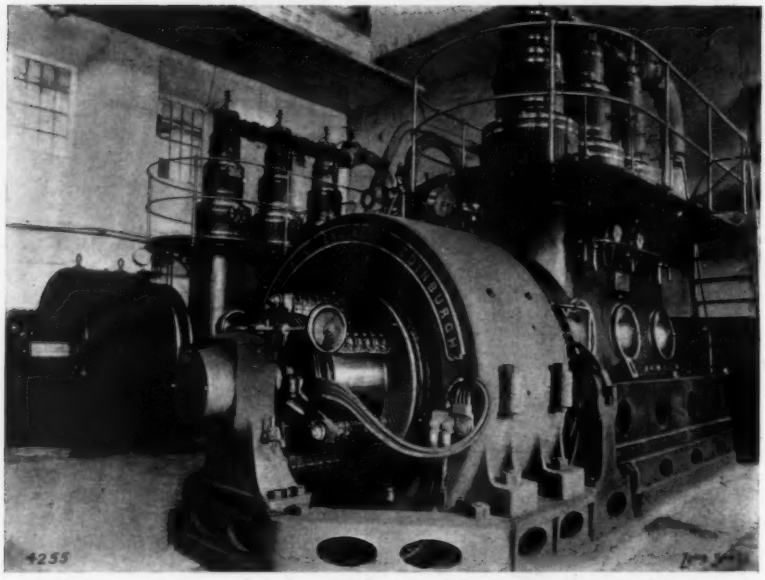


FIG. 2.—LINWOOD PAPER MILLS: THE ENGINES AND DYNAMOS.

at an average temperature of 160 degs., and is discharged into the boilers at a temperature of 300 degs. more or less.

The feed-pump is by Messrs. G. & J. Weir, Ltd., Cathcart, and is of single direct-acting steam-driven type. It has a single cylinder, double-acting and vertical. The pump end is of cast-iron fitted with gun-metal liner, the pump rod of cold rolled manganese bronze. The water-valves are of the Weir patent group type of special bronze, in gun-metal seats. The water pistons, or buckets, are of gun-metal with ebonised packing rings. The valve-gear is positive, *i.e.* the steam valve can never be in such a position that the pump will not start immediately when the steam is turned on. The dimensions of the pump are:—Pump cylinder, 8 ins. diameter; steam cylinder, 10½ ins. diameter by 21-in. stroke, having a capacity of 5,000 gallons of water per hour, delivering against a pressure of 260 lbs. per square inch. The normal speed of the pump is 12 double strokes per minute.

The condensers consist of a pair of twin air-pumps, each having a diameter of 16 ins. by 10-in. stroke, driven by an inverted twin compound engine with cylinders 6 ins. by 12 ins. diameter, and 10-in. stroke, the speed being 125 revolutions per minute. The air-pumps are single-acting, fitted with suction bucket and discharge valve; the outer casing is of cast-iron, while the liners, valve gearing, and guards, are of brass.

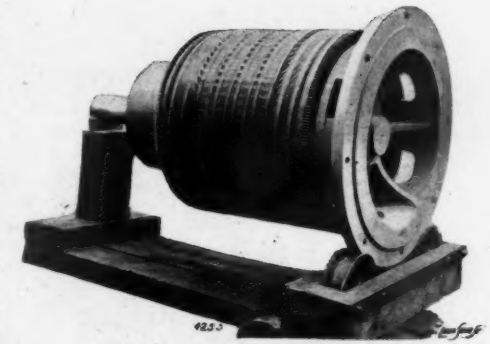
The filters are by Messrs. Bell Bros., Ravensthorpe, and they are constructed to withstand a working pressure of 270 lbs. per sq. in. The feed water from the hot well is pumped through these filters, and from there through feed-water heater and economiser to boilers.

There is no water softening process in connection with these filters, the nature of the water being such as to render this unnecessary. There is, however, from time to time, a considerable quantity of suspended matter in the water supply, all of which is thoroughly removed by the

filtering process; and arrangements are made whereby the filtering medium can be thoroughly cleansed without interfering with the working of the plant.

The engines to which the dynamos are coupled (Fig. 2), are of the Willans type, triple expansion with three cranks, and designed for working with a maximum steam-pressure at the throttle valves of 250 lbs. per sq. in. The combined efficiency of the set on test was found to be 85·5 at full load, and the steam consumption does not exceed 12·5 lbs. per i.h.p. per hour at full load.

The dynamos consist of two Bruce-Peebles "P.P.P.," No. 20 type, six-pole machines, sectional photographs of which are shown at Figs. 3 and 4. Each machine is capable of a normal output of 300 kilo-watts (1,500 amps., 250 volts), running at a speed of 340 revolutions per min., with a temperature rise not exceeding 65 degs. F., after continuous running. The machines are designed to run absolutely sparklessly under all conditions of load up to 25 per cent. over full load, and in this, as well as other respects, they have given every satisfaction. The armatures, as will be seen from Fig. 3, are of Bruce-Peebles flywheel spider type, that is to say, the machine is not coupled to the shaft in the ordinary manner, but by an extension of the spider on which the core is built up. The armature is slot wound with compensate winding, fitted with special compensating bars to ensure that all the brushes take an equal proportion of the load.



FIGS. 3 AND 4.—VIEWS SHOWING DYNAMO PARTS.

The commutators are built up on Messrs. Bruce Peebles' patent hydraulic system, and are so rigid that they can be struck in the centre with a heavy hammer without in any way affecting the commutator bars. Dropped bars in commutators built up in this way are an impossibility.

The motor equipment consists of eight 80-b.h.p. motors, two 50-b.h.p. motors, and ten 25-b.h.p. motors. All these motors are of Messrs. Bruce Peebles' standard "P.P.P." power type. Six of the 80-b.h.p. motors drive the beating engines. Fig. 5 shows two sets of beaters each with their 80-b.h.p. motor. These machines are used for reducing the raw materials, manilla, flax, and jute into pulp, and may be said to form the commence-

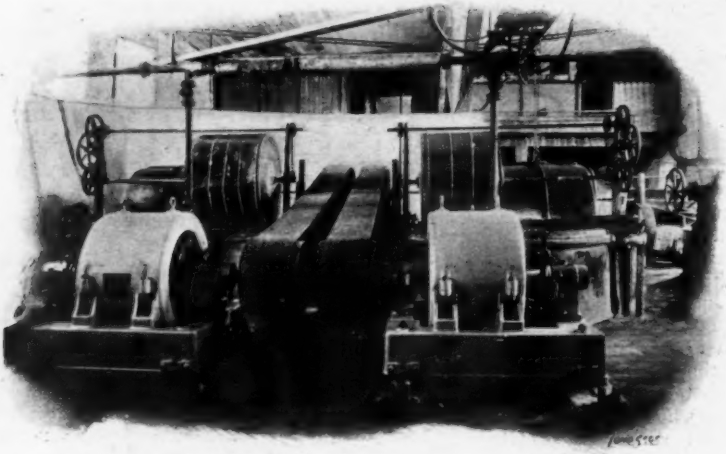


FIG. 5.—THE BEATERS WITH THEIR 80-B.H.P. MOTORS.

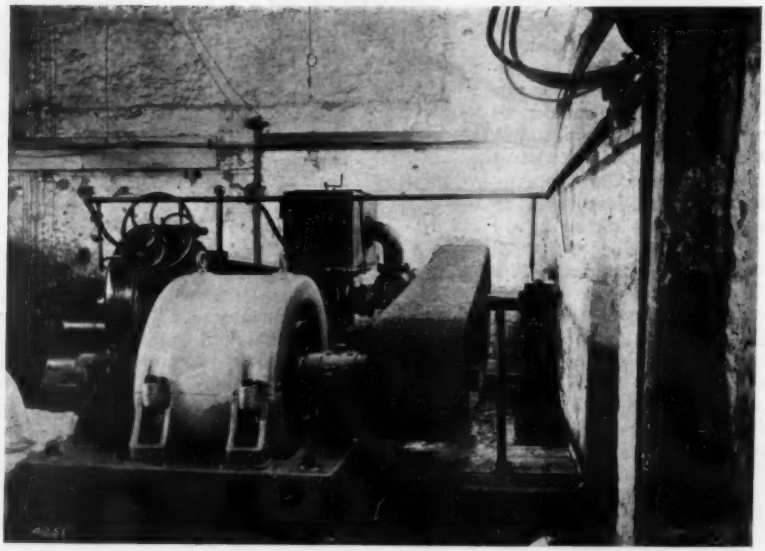


FIG. 6.—MOTOR FOR DRIVING THE PULP-REFINING MACHINE.

ment of the paper manufacture, in so far as power is required.

The working stresses during the initial stages of the pulp process are of a most variable character, and considerable doubt was felt as to the likelihood of a motor drive being successful; but the results now obtained justify the application, as the motors have proved quite equal to all conditions of working, and readily respond to an overload of 50 per cent. without heating or other trouble.

Owing to the sudden and sometimes excessive variation of the load of these machines, it was thought advisable to adopt a belt drive, and this has proved quite successful.

Fig. 6 shows another 80-b.h.p. "P.P.P." motor for driving the pulp-refining engine. These machines are used for treating the pulp after it comes from the beating engine, the crude pulp being pounded into a pasty consistency preparatory for transmission to the paper-making machine, in which it passes through the various stages required to complete the manufacture.

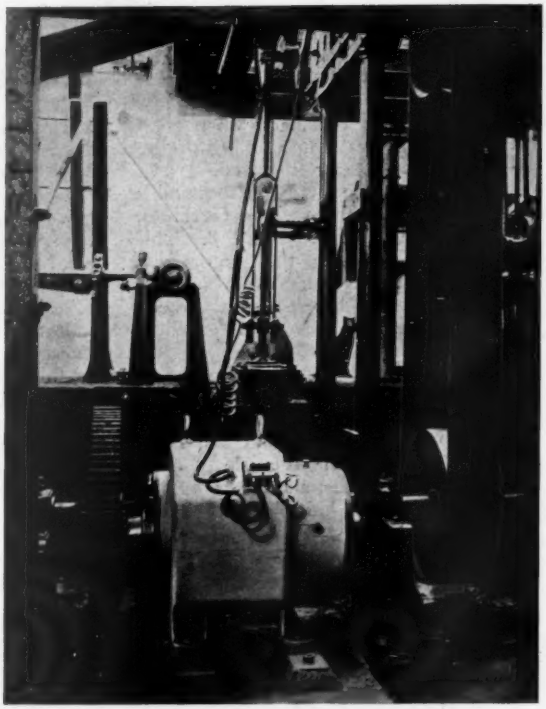


FIG. 7.—MOTOR DRIVING AUXILIARY PLANT.

The two paper-making machines, including accessories, are each equipped with two motors, one having a 25-b.h p., and a 50-b.h.p. motor, and the other one two 25-b.h.p. motors. The power necessary to drive these machines is dependent upon the weight and quality of the manufacture for the time being, but the provision made fully meets all requirements in this respect; and, what is of primary importance, the speeds can be regulated with absolute exactitude.

The auxiliary plant of the paper-making machine, consisting of pumps, agitators, etc., are worked from lines of shafting, which are driven by motors, as illustrated in Fig. 7. The web of paper, on being taken from the machine, is passed through the rolls of the damping machine, which is also driven by a 25-b.h.p. motor, as illustrated on Fig. 8. This damping process is preparatory to calendering, which is the final stage of the manufacture. Fig. 9 is an illustration of one of the large calenders, which is driven by an 80-b.h.p. motor. The rolls of the calender have to be adapted to suit the various thicknesses of the paper, and the speed has also to be regulated in accordance with the nature of the paper, and the degree of finish or surface necessary. To meet these requirements, the calender motors are of the variable speed type, being designed to run from 100 revolutions to 600 revolutions per minute. A

speed of 100 revolutions per minute is only necessary on starting the machine, and from 300 to 600 revolutions per minute (the average limits); the variation can be regulated by the shunts, the loss being negligible, particularly when compared with the wasteful working of the steam engines formerly employed.

A number of the motors in these mills are geared up to the various machines, as shown on Figs. 6, 7, and 8. This method of connecting the motors was necessary in some instances to suit the space at disposal, but it has also been adopted in other cases with excellent results.

With a view to testing the different materials used for gear pinions, Messrs. Watson, with their consulting engineer, Mr. R. D. Munro, carried out a series of experiments with pinions made of phosphor bronze, raw hide, and paper. Phosphor bronze and raw hide pinions, although running fairly well, are very noisy, which in several of the departments was objectionable, and for this reason it was decided to use pinions made of paper. These pinions are composed of paper specially manufactured by Messrs. Watson, discs being cut from the web, and built up like an armature core. The paper discs forming the paper are bound together by iron hoods or caps, and one of these wheels, about 12 in. diameter, which has been working into an ordinary spur for the last three years, has given no trouble whatever, and is still in good order. The other pinions of various sizes are also turning out equally satisfactorily, and this method of manufacturing paper pinions is likely to be largely taken advantage of.

The whole of this installation has been designed and carried out by Mr. R. D. Munro, M.I.Mech.E., Chief Engineer of the Scottish Boiler Insurance Co., Glasgow; and, with a few unimportant exceptions, the electrical portion of the work has been manufactured and erected by the contractors, Messrs. D. Bruce Peebles & Co., Tay Works, Edinburgh.

Power users will, of course, be mostly interested in the question of the economy of this whole system as compared with that of using isolated steam engines; and, consequently, some considerable pains have been taken to get at the exact cost of the consumption, and the units used throughout the year during which this plant has been working.

The capital cost of the 600 kilo-watts generating plant, including engines, dynamos, boilers, condensers, steam piping, filters, etc., and all engine room accessories	£9,500		
The proportion of which is utilised for the present motors, allowing 25 per cent. additional for spare, brings the capital outlay on the generating plant for the actual number of motors installed during the year to ...	£5,950		
Allowing 10 per cent. for interest and depreciation on this we get ...	£595		
Which, per week		£11	8 0
The average amount of coal consumed per week, 58 tons 18 cwts., which at 4s. 10½d. ... ... per ton		£14	7 1
Carriage at 4d. per ton ... ... per week			19 8
Wages: Stokers, Engine Driver, and Greaser		£3	10 0
Oil and Stores			12 0
Total		£30	16 9

An important point to note is that, as will be seen from the description, the generating plant is equipped throughout for a full continuous load of 600 kilo-watts. The engine house is of sufficient capacity for a further 600 kilo-watts, making a total final capacity of 1,200 kilo-watts.

At present, only one-third of the whole mill is completely equipped, the remaining two-thirds being in process of conversion, the final scheme being to employ three-fourths of the plant on load, leaving one-fourth as spare. The load on the motors

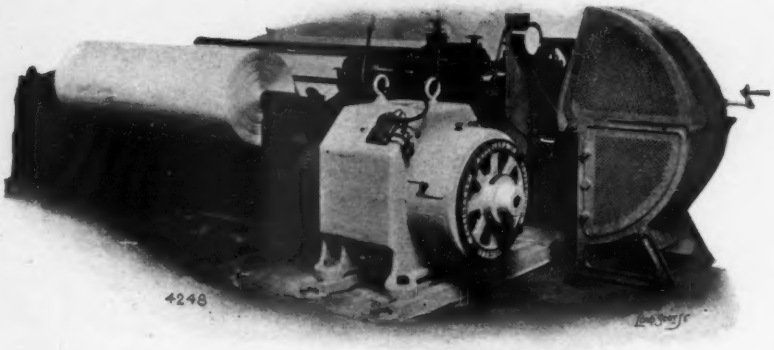


FIG. 8.—DAMPING MACHINE DRIVEN BY A 25-B.H.P. MOTOR.

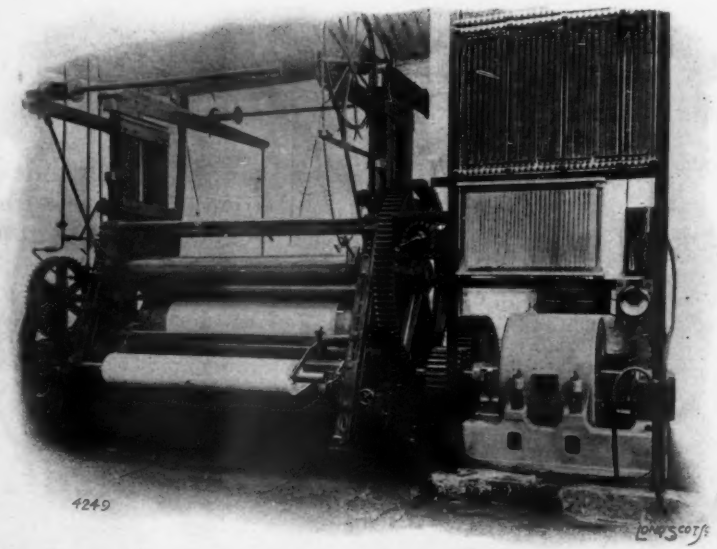
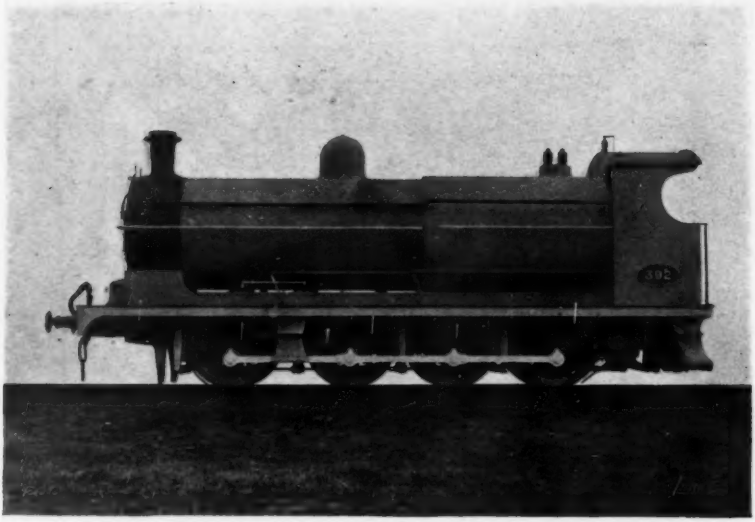


FIG. 9.—MOTOR-DRIVEN CALENDER.



EIGHT-WHEELED COUPLED GOODS ENGINE, WITH CORRUGATED FIRE-BOX, LANCASHIRE AND YORKSHIRE RAILWAY.

at present is just sufficient to fully load up one of the 300 kilo-watt sets; so, in estimating interest and depreciation, it would not be fair to take the full amount of the 600-kilo-watt set, part of which would be utilised for further motors, but to take a *pro ratâ* cost of the plant necessary to supply the present 300 kilo-watt in motors, *i.e.* 400 kilo-watts, which allows 35 per cent. additional as spare.

Average of total units generated per week, taken over the same period as the other costs, equals 29,380 (corresponding to 70 per cent. load factor). Therefore, the total cost per unit

$$\frac{£30\ 16s.\ 9d.}{29{,}380} = \cdot 259 \text{ pence per unit.}$$

Thus, on the above figures, the actual generating costs, including labour, attendance, and allowing the above ample allowance for interest and depreciation, works out at about a farthing per unit.

As a matter of fact, it is claimed that the saving in coal alone on this plant will pay off the first costs in about five years. This economy is quite apart from the considerably less labour in the actual processes, and from the ease in handling, and the facility at which the speeds of the various machines can be altered to suit the particular process with which they are working.

Eight-Wheeled Coupled Goods Engine, with Corrugated Fire-box.

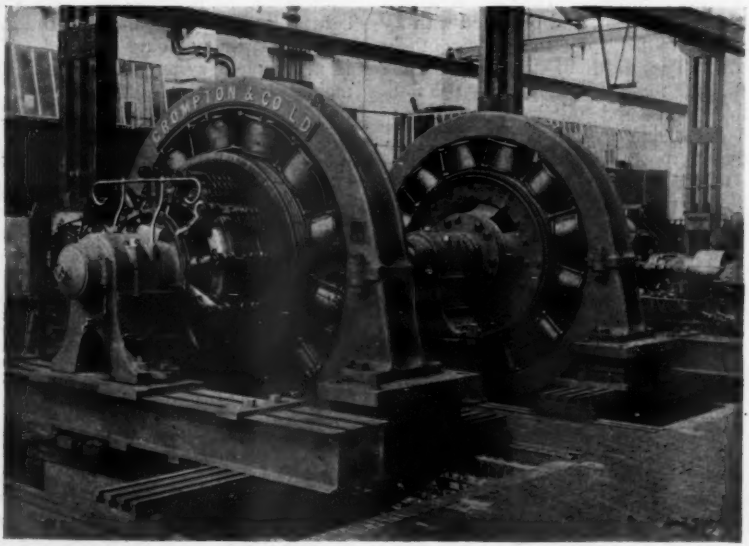
THE accompanying illustration shows the latest type of eight-wheeled coupled goods engine No. 392, built for the Lancashire and Yorkshire Railway Company at the Horwich Works. The engine is from an original design by Mr. J. A. F. Aspinall, the present General Manager, when Chief Mechanical Engineer, but is fitted with a boiler designed by the present Chief Mechanical Engineer, Mr. H. A. Hoy.

There are several points of difference between No. 392 and the old form of eight-wheeled coupled locomotive of the

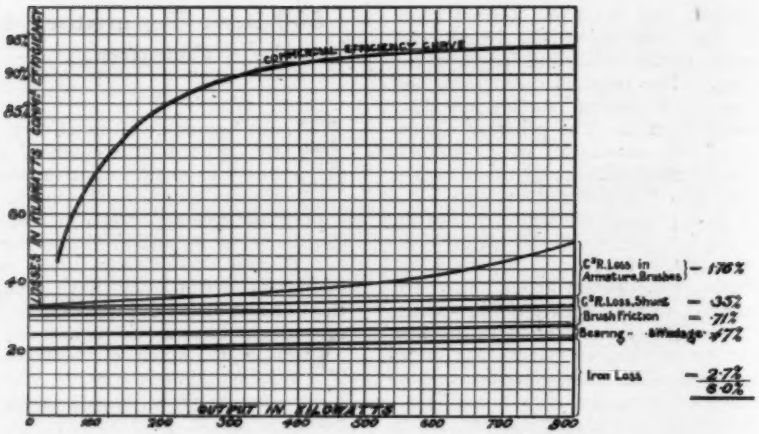
Lancashire and Yorkshire Railway Company, the chief being the length and diameter of the boiler and length of the fire-box. The latter is corrugated, and 135 sq. ft. of heating surface are thus obtained from it. The principal dimensions of this locomotive are as follows: Cylinders, 20-in. diameter by 26-in. stroke; wheels, 4 ft. 6 ins. diameter; wheel-base, 16 ft. 4 ins.; centre of leading to driving, 5 ft. 11½ ins.; centre of driving to intermediate, 5 ft. 2¼ ins.; centre of intermediate to trailing, 5 ft. 2¼ ins.; boiler, 5 ft. 5¼ ins. diameter; length between tube-plates, 12 ft. 9 ins.; fire-box, length of flue, 9 ft. 6 ins.; ditto, diameter over corrugators, 5 ft. 1½ in. tubes, No. 281; outside dimensions, 2 ins. Heating surface: Tubes, 1,882 superficial feet; fire-box, 135 superficial feet; total, 2,017 superficial feet; fire-grate, 33 ft. Capacity of tank, 2,290 gallons. Weight of engine loaded: Leading wheel, 14 tons 6 cwts. 1 qr.; driving wheel, 15 tons 8 cwts.; intermediate wheel, 15 tons 2 cwts.; trailing wheel, 13 tons 2 cwts. 2 qrs.; total, 57 tons 18 cwts. 3 qrs. Weight of tender loaded, 30 tons 13 cwts. 1 qr.

800-K.w. Generators for Calcutta.

EARLY last month Messrs. Crompton & Co. invited a number of guests down to their extensive works at Chelmsford for the purpose of viewing the recently completed lamp and instrument shops, and to witness the final test of two 800-kilowatt direct-current generators which they have built for the Calcutta Electric Supply Corporation, for whom Messrs. Crompton are contractors for the whole of the machinery. The older portion of the works, where the heavy machinery is manufactured, is a building 240 ft. long by 260 ft. wide, divided into eight large bays, and with a floor space of 63,000 sq. ft. The roofing is of the "saw-tooth" pattern, and the lighting exceptionally good. Five of the bays have electrically-driven travelling cranes, and the other three hand-power cranes. The shops are equipped throughout with electric motor drives, and pro-



800-K.W. GENERATORS FOR THE CALCUTTA ELECTRIC SUPPLY CORPORATION.



800-K.W. GENERATORS FOR CALCUTTA: EFFICIENCY CURVE.

vided with sixty arc lamps for artificial lighting when necessary.

The new lamp and instrument shops, which were nine months in course of construction, are close to the dynamo shop, from the power-house of which they obtain all their current. They are laid out entirely on one floor, and provided with a north light roof, also of the "saw-tooth" pattern. The width of the building is 270 ft., and the length at present 160 ft.; but this can be indefinitely extended, the north end being of light corrugated iron for this purpose. The height from the floor to the inside of the roof beams is 13 ft. over the greater portion, and 15 ft. at one end, which is shut off from the rest and used as a packing room. A space of 40 ft. by 60 ft. is divided off at the west side of the shop, and forms the instrument department, and the rest comprises the lamp and switch departments. A space 55 ft. wide across the whole north end of the building is reserved as a store, and a portion of this is again divided off for a tool-shop, which is completely self-contained. The machine-shop occupies the centre of the building, the east side being given up to the manufacture of arc lamps, and the west side to switches, switchboards, projectors, etc. On the south side are the offices of the shop manager, draughtsmen, and office staff. The shop is floored throughout with American maple boards, laid on an under floor of deal with concrete below. The use of rails is unnecessary with this floor, and all machine-tools can be bolted down without special foundations. The shop is lighted by arc lamps, those in the instrument department being inverted. There is a complete system of fire mains, and mains for the supply of "Dowson" gas, used for brazing, soldering, etc.; and the whole shop is motor-driven. There are four lines of motor-driven shafting running on roller bearings, and a large plant of interesting and up-to-date tools in both departments.

We give an illustration of the two multipolar shunt-wound direct-current generators for the Calcutta Electric Supply Corporation mentioned above, which at the time of our visit were undergoing the Hopkinson efficiency; test and also a reproduction of an efficiency curve. Each of these machines is capable of an output of 800 kilo-watts at a speed of 230 revolutions per minute and a voltage of 550. They are fitted with slotted drum-wound armatures 7 ft. in diameter, the magnets are compound wound, the outside diameter of the yokes being approximately 12 ft. The poles and pole faces are all in one

piece, and each is bolted to the yolk. The field winding is held between brass flanges, which are connected diagonally with screwed iron tubes. The commutators are fitted with carbon brushes, the brush-holders being attached to spindles carried on radiating spider-arms; and all bearings are self-oiling. The net weight of the armatures is 13 tons each, the total weight 30 tons for each machine. Although primarily designed for lighting purposes, the generators embody all the essential qualities of dynamos for traction purposes, and could be used equally well in that capacity.

It will be seen from the efficiency curve that the commercial efficiency is 94 per cent., the losses being made up as follows:

	Per Cent.
C^2R loss in armature and brushes	1·76
C^2R loss, shunt	·35
Brush friction	·71
Bearings and windage	·47
Iron loss	2·7
Total	5·99

The temperature rise after six hours' full load 50 degs. Fahr. in the armature and 37 degs. Fahr. in the field, these low rises being necessary owing to the heat in which the machines will have to work.

A large number of electrical engineers were invited to witness the test, and amongst those who attended were Colonel Filgate (chairman of the Calcutta Electric Supply Corporation and of the Hove Electric Lighting Co.), Sir Guilford L. Molesworth (a director of the Calcutta Electric Supply Corporation), with S. Eustace, Esq. (chief engineer), James Swinburne, Esq. (President of the Institution of Electrical Engineers). Most of these gentlemen were met at Liverpool Street Station by Lieut.-Colonel R. E. B. Crompton, R.E., C.B., accompanied by F. R. Reeves, Esq. (general manager) and H. Stevenson, Esq. (chief engineer at Messrs. Crompton & Co.'s London office), and travelled in saloon carriages to Chelmsford, where brakes were in waiting to convey them to the Arc Works. Here they were received by S. L. Brunton, Esq. (works manager), W. L. Pakenham, Esq., and other members of the staff, and escorted to the test-room, where a test was conducted under the superintendence of F. R. Markham, Esq. (chief of the department).

Subsequently the party was conducted through the works by Colonel Crompton.

The Wolverhampton Exhibition.—IV.

(Continued from page 168.)

THIS pump is driven by a 10-b.h.p. standard "P.D.M." semi-enclosed motor. This motor is also of the 4-pole type, with slotted drum brushes. The bearings in this machine are of the spherical-seated, self-aligning type, and have two rings per bearing for automatic lubrication. The whole of the brush gear, rocker, etc., is easily accessible by means of the two doors at commutator end. All openings on the motor are covered by means of perforated brass sheet, and the terminals are also fully protected by means of a cast-iron cover.

Should the motor require to be worked on its side by bolting to a wall, or even on the underside of a roof, the end covers are so drilled as to permit of this.

The temperature rise of this machine, after a run of six hours, full load, does not exceed 75 degs. Fahr. above the surrounding atmosphere. This machine has also been made by the Phœnix Dynamo Manufacturing Co. of Bradford.

On the motor-shaft is fitted a rawhide pinion gearing into a spur-wheel having machine-cut teeth. The motor is bolted to cross-stays, which are firmly fitted to standards by turned and fitted bolts, making an exceedingly rigid framework. It will be noted that by this arrangement the intermediate shaft and gearing are dispensed with, thus saving in friction and wearing parts.

The duplex pump is fitted with Bever's patent valve-gear, the advantage of which the following description and illustration will show. Each piston-rod, instead of only working the valve of the other cylinder, also works the valve of its own cylinder. The levers from both piston-rods are coupled to a lever marked *A* on

the drawing, imparting to it a motion of the two piston-rods. The object of this is to give each valve lead just like a valve worked by an eccentric; secondly, to cut off the steam before the end of the stroke. This is generally done at about $\frac{5}{8}$ or $\frac{3}{4}$ of the stroke. The advantages claimed for this method of working are given as follows: (1) The pumps can be worked at a very high speed. They have been run up to 300 double strokes per minute, or a speed of 600 ft. for a 12-in. stroke pump. (2) The early cut-off causes a saving in steam, as in the ordinary duplex pump the steam is not cut off until after the completion of the stroke, so that the full steam pressure is acting on the piston whilst it is stationary. (3) As each piston-rod governs its own valve as well as that of the other cylinder, the two sides always make an equal length of stroke instead of a long stroke and a short one, as frequently occurs with the ordinary duplex. (4) The lead given to the valve has the effect of stopping the piston and preventing its striking the covers, as occurs with the ordinary pump, particularly when exhausting into a condenser.

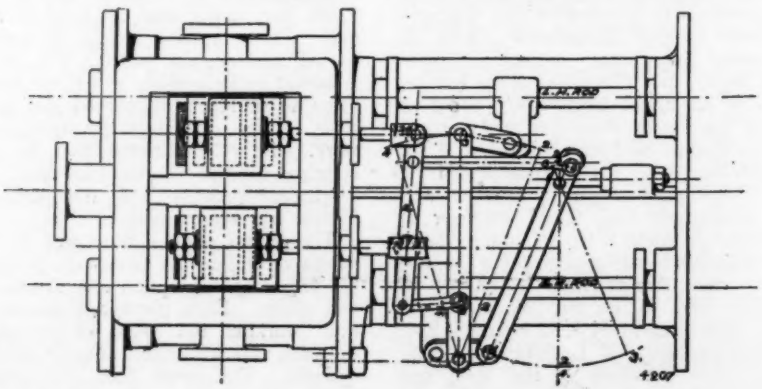
The drawing indicates the working of the gear, and it will be seen that the right-hand side is at the end of its stroke, and that the valve has opened the port to the extent of the lead for the return stroke, whereas in this position with the ordinary gear the valve would still be open at the other end although the stroke was completed. The left-hand side is at mid-stroke and has a full port opening, which, however, immediately after closes very quickly, and is generally arranged to cut-off at $\frac{3}{4}$ or $\frac{5}{8}$ of the stroke. The great speed, of course, very much increases the pumping capacity, in addition to which there is a great saving of steam and more regular working.

This pumping engine is manufactured by Messrs. Bever, Dorling & Co., Ltd., of Dewsbury, and has steam cylinders 6 ins. diameter, 4-in. pumps, and 10-in. stroke. The pump-valves are of a special quality of rubber beating on gun-metal valve-seats; the pump-rods are of a special brand of manganese bronze, and the valve-gear is made under Bever's patents. An automatic self-starting and stopping arrangement can be also successfully applied.

On the stand these two pumps are shown delivering their water in the fountain, forming a circular cascade.

The switchboard, as used at the exhibit, was supplied by Messrs. Hodgson Wright & Wood, and embodies their standard type of switches.

A further electrical exhibit on the stand consists of four "Cod" patent arc lamps, made by the Cod Arc Co., of Nottingham. These lamps will be found to be one of the most simple in mechanism and embody several important improvements.



BEVER AND DORLING'S DUPLEX PUMPING ENGINE (WOLVERHAMPTON EXHIBITION): VALVE GEAR.

Workshop Practice

Practical suggestions for this section are invited, which, if accepted, will be suitably paid for. Wherever possible, drawings should accompany the contribution; rough sketches will suffice. Nothing will be too poor for a careful inspection. See important announcement in advertisement pages.

Working Limits.

NOTHING can be more annoying to a painstaking mechanic than to see a piece of work, on which a great deal of time and energy has been spent, going to the scrap-heap. When we inquire into the reason why, we often find that the instructions were not as clear as they might have been. We may read on drawings or hear it expressed, "not particular," "accurate," "dead size," "bare," "full," a "trifle" or a "shade" under or over, etc. Now what actual value are these expressions? If you have a sketch, as in Fig. 1, they are perhaps a little better than nothing at all, but can never give satisfaction. It would no doubt be different if the mechanic had got a general drawing or the machine itself where the job is a part, he then can use his own judgment. No doubt we all know that accuracy to within ·0001 is costly and seldom needed for the best of engineering, therefore we should only work to such limits that practice has proved does not interfere with the good working of a machine I have used for some time the mill. ('001 of an inch) as a unit in expressing the limits above or below standard, and found it saved a good deal of time, as the workman knows what is actually wanted. A few examples, I think, will make the working clear. In Fig. 2 we have a plug to be a driving fit in a 2-in. hole, and to be ·0025 to ·003 above size. Again, in Fig. 3, we want plain end *A* to make a shrinking fit, and to be ·002 to ·0025 above standard; *B* and *D* to be rimering fits and ·001 to ·0014 below standard; part *C* is clearance, and may be ·01 above or below size; *E* being a light driving fit ·0001 to ·0003 above size, and *F* 4 shows the working limits of a limit gauge. I am well aware that special limit gauges for the different fits are made, but they do not cover all conditions to be met in engineering workshop practice.

H. HELLFRITSCH.

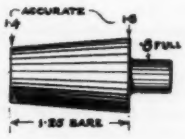


FIG. 1.

FIG. 2.

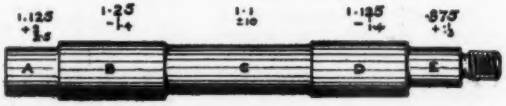


FIG. 3.

FIG. 4.

WORKING LIMITS.

Forcing off a Wheel.

Considerable difficulty is experienced at times in removing a wheel from a shaft, especially when in close position to another one, further increased when the wheel is "dished" as shown in section at Fig. 1. As it is part of my duty to remove wheels of this description very frequently, I think my method will be of interest to those of your readers who are brought in contact with jobs of this kind, or who may be engaged in general millwright work. My experience of the use of a drift and the help of a striker, very often resulted in one or more of the wheel arms being broken through the vibration, as the "sett," or drift had to be inclined at about 70 degs. to get an effective drive, the want of space making it very awkward to strike, but with the following device the trouble is now dispensed with and broken wheels avoided. The arrangement consists of a piece of 2-in. square iron, with holes bored at convenient centres to suit the boss diameter. These holes are used for locating hook bolts which are placed behind the wheel arms and close up to the boss, as shown at Fig 2. The bar is also provided with a recess in the centre, slightly larger than the shaft, and about ¼ in. deep. The bar is fixed in position across the wheel, and a few light blows given with a hammer. The bolts being tightened up as the wheel is drawn forward.

BARRACLOUGH MORTIMER.

[In some cases it might be necessary to interpose a short piece between the end of the shaft and the bar, when the boss of the wheel was some distance through. ED?]

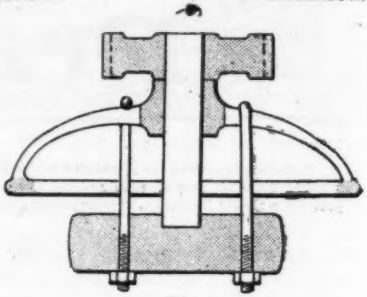


FIG. 1.

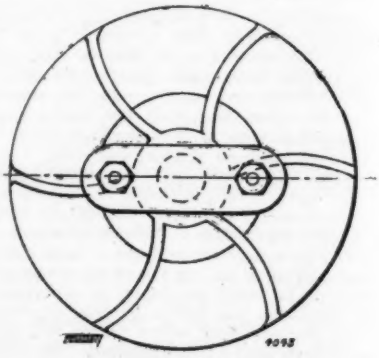


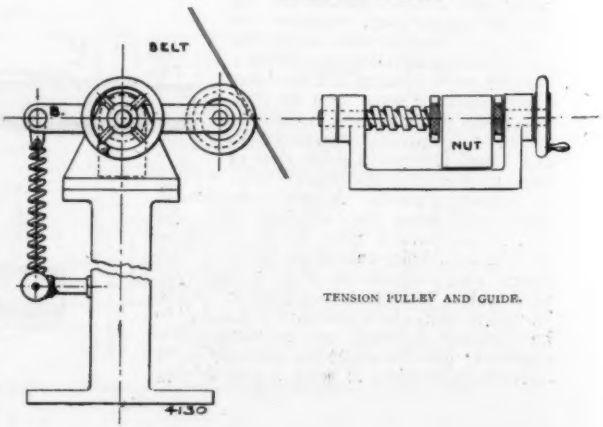
FIG. 2.

FORCING OFF A WHEEL.

Tension Pulley and Guide.

In order to overcome the difficulty in connection with a short belt drive, the improvised arrangement shown at Figs. 1 and 2 effectually met the trouble in moving the strap from the fast to loose pulley, and *vice versâ*. A cast-iron pillar was used for the purpose of supporting the casting of a lathe headstock which was utilised for carrying a screw (collared at one end), which engaged in a nut, the latter supporting two wrought-iron bars, which in turn carried the flanged guide-pulley, as shown. A spiral spring fastened to a stud in the pillar, and the end of the bars *B* kept the required tension, the pulley being run on a large bush to reduce friction. By means of a hand-wheel attached to the screw at the back, as shown, the belt was moved to the desired position.

P. ROBINSON.

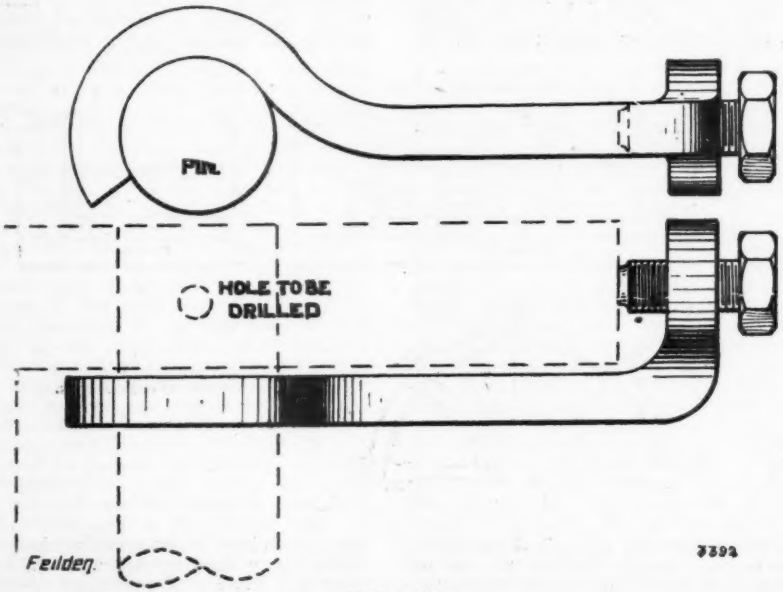


TENSION PULLEY AND GUIDE.

A Set Pin Clamp.

The device shown is a useful clamp for holding shafts, etc., in position whilst being drilled for set or split pins. It is made as a forging from mild steel about ¾-in. square section, and bossed up as shown to receive a ½-in. set screw with hexagon head, the bend is also thickened to give additional strength. It is particularly adapted for holding shafts or pins when the hole has been drilled through one portion only, or where existing holes are being used.

J. G. B. S.

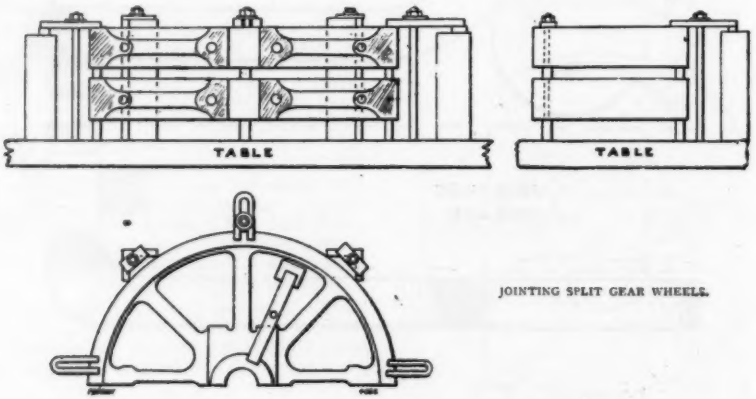


A SET PIN CLAMP.

Jointing Split Gear Wheels.

In the better-class machine-tool work and the modern method of chain-driving, the demand for machine-cut wheels has necessitated, to a very great extent, the use of iron patterns, also machine-cut, from which are made the castings for the working wheels. For convenience in erecting, and to reduce, as far as possible, the initial strains set up in cooling, the latter type of gears are frequently made in halves, which are afterwards machined and bolted together to form the finished wheel. In the methods adopted to ensure accuracy, with a minimum amount of labour, it is essential that the cycle of operations be as perfect as possible, and also in order to meet the exigencies of breakdowns, quick delivery and economical production. The primary object in the machining of wheel castings is that, when finished, they shall always return to the original position, no matter how often they are taken asunder. To satisfactorily accomplish this, the methods described are recommended as being found the best of all previous ones, ensuring the best results with the least work. After the castings have been well pickled in a mixture of vitriol and water, they are fixed on the machine table, the bottom half being placed on three parallel packings, one at either end and one in the centre, the rim only resting upon them. On the top of the first half three other packings are placed directly over the under ones, these being high enough to keep the faces of the bosses on both halves from touching, and on these the second casting is mounted. The upper edge of top half should be set parallel from table, so that when finished and the top half is turned over to make the whole wheel, it ensures one edge of wheel being true. When the two halves are set they are cramped

down, care being taken to put the cramps over the packings, so as to avoid springing the castings, an adjustable packing is fixed between the table and the bottom face of boss, and another between the two boss faces; a cramp is put on the top, over the line of bosses, thus holding the centres of the castings firmly while the milling is done. The upper half is marked out to show how much has to be cut off. Two angle-plates are fixed on the table, as shown in sketch, and act as a guide by which the halves are kept level. A large face mill with inserted teeth is used, and two cuts are taken, the first a roughing and the second a light finishing cut. When the halves are milled, the table is then moved back and they are



JOINTING SPLIT GEAR WHEELS.

set out for drilling, which is done without the castings being disturbed beyond the removal of the cramp over the bosses, leaving the others untouched. The sketch shows two holes in the boss and one hole at each end, near the rim, in both halves. The holes in the bosses are made clearance, and the rim holes are drilled and rimered templet size. By making these holes templet size and using fitted bolts, it is evident that the halves will always come into the same position, however many times they may be taken apart. In setting the halves out for drilling no elaborate work is needed; all that is done is to get the pitch of end holes of one half and the horizontal centre line of each half, and the rest can be done on the machine, as the horizontal and vertical slides are graduated. The setting out finished, we commence drilling at hole *A* (see sketch), which is rimered also; then raising the head the required height, to the centre of *B*, which is done by measuring the distance between the two centre lines and raising the head the right height by means of the graduations on upright. After drilling and rimering *B*, we move along the slide to *C* and drill that, and then to *D* (these two, being clearance holes, do not require rimering); then to *E*, which is drilled and rimered, and lower the same distance that it was raised to *F*, and then along the slide again to *G* and *H*. It will be noticed, by following this process on sketch, that the templet holes at each end are drilled and rimered without moving the upright on the slide-bed, thereby making sure that the pitch of these holes is the same in both halves, and that there will be no filing or drawing required to make the bolts fit. When all the holes are drilled, a bar carrying a cutter faces up the bolt bosses true with the holes. This work is done on a horizontal boring, milling, and drilling machine, which has a movable table at right angles with the slide-bed.

C. H. G.

Green Sand Wrinkles.

In the numerous designs and arrangements which it is necessary to make in order to overcome some difficult detail in machinery, few parts lend themselves, or are more subject to alteration, than gearing. The disposition of the bosses, the relative position of arms to rim and other variations, necessitate the alteration

of the standard wheel-pattern from time to time. These departures are most frequently accomplished by the use of dry-sand cores, made to suit the several jobs, with the addition of the necessary preparations on the pattern to receive them. This method is in most cases satisfactory, but the main objection is the cost for pattern-making when a single casting only is required; therefore the purport of these notes is to illustrate in a practical manner the modification of green-sand moulds, the manipulation of strickles and other preparations, whereby a casting of a given form can be produced at a minimum cost. The several examples given will supply methods applicable to other work than that described, and will prove useful alike to both pattern-maker and moulder.

Rising a Wheel Pattern.—A spur-wheel pattern of 1½-in. pitch, used for a special purpose, and having arms of elliptical section, was increased 3-in. in width on the working face—keeping the arms central—by the following method. The pattern (Fig. 1) was "bossed" up in the usual manner, the distance through the boss being equal to the finished casting, plus the allowance on each face for machining. In moulding, the pattern was set on a level bed of sand, and well packed both inside the rim and on the outside of the teeth with facing-sand, to about 3-in. deep. It was then lifted out, and three or four small pieces of timber, say 1½ in. long—planed up square, and representing in width and thickness half the amount of the required increase—were set in the bottom of the impression or mould, and directly under the rim. The pattern was returned to position, the ramming-up being continued to the centre line of the arms, where a level joint was formed and prepared with parting-sand in the ordinary way. A strickle, as Fig. 2, made of 1-in. timber, was used for the purpose of forming a "rising" joint, the height from the edge *E* to *J* being equal to half the increased width, and a pin at *P*—fitting a hole in the boss—assisted to steady the strickle whilst being swept round to form the joint *J*, which eventually represented the top edge of the rim. The radius of the strickle at *E* is made about 1 in. greater than the pattern, in order to allow a thickness of facing-sand against the teeth, upon the pattern being raised to the level of *J*. This joint, together with that on the lower plane, was freely sprinkled with parting-sand, and a top part moulding box was then "staked" in position, the depending body of sand being well supported with "gaggers," and upon completion of the ramming the box part was lifted, the runner and "risers" being previously set in their respective places. The pattern was then raised to *J*, and the ramming up of the teeth was completed to this level, thus giving the required increase in width, and retaining the arms in a central position. The section of sand left on the top part at *S* (Fig. 3), previous to the final elevation of the pattern to *J*, was pared away to that level and to the taper on the inside of the rim. The dotted lines on the top and bottom side of rim at Fig. 1 represent the increased width in casting. Wheels with solid centre-plates in place of arms are sometimes required with the plate out of centre, or moved wholly to one side. These modifications are easily accomplished with the aid of a few strips of timber planed up to a thickness corresponding to the amount the plate is to be moved, and are used as follows:—The pattern (Fig. 4) is "bossed up," so that the faces of the bosses are at the required distance from the edges of the rim *E E'* on either side. For moulding the pattern is laid on a turn-over board, or a box-part filled with sand strickled off to a level face; a bottom part-box is placed over it, and rammed up in the usual manner. The box enclosing the pattern is then turned over, and three or four of the strips are laid on the top side of the plate. The face of the mould is prepared as a joint with parting sand, a top part-box is put on, and the ramming up proceeds with the usual arrangement of runner and riser. On the completion of the ramming the sand is cut away to the level of the strips, the latter being then transferred to the surface of the sand in the bottom part-box, which forms the inside of the casting. The addition of some facing-sand to the face of the strips increases the height in proportion to the reduction made on the top part, thus moving the original position of the recess, forming the plate, in the mould to any required distance within the limit of width. The inclination of the sides of the raised portion of sand is continued to the level surface, the edge rounded with a "smoother" to form the hollow or fillet within the casting. The loose strips are then withdrawn, the cavities left by them filled up, and a little extra smoothing, after blackening, completes a successful alteration. When the plate is all on the one side the top side of the pattern may be considered as a level surface, and a top part rammed and set over it, the interior cone of sand on the underside being raised, as before, to suit the required thickness of plate, with the boss continued to the same level.

Stopping off.—A wheel pattern may be "stopped off" to any required width on top or bottom sides or on both, by means of a strickle (as Fig. 5), used for the top side, and

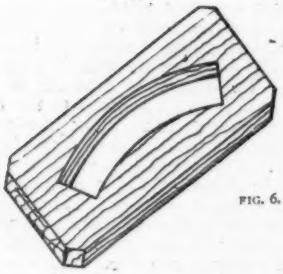


FIG. 6.

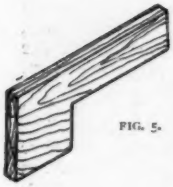


FIG. 5.

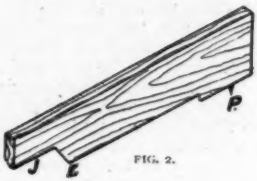


FIG. 2.

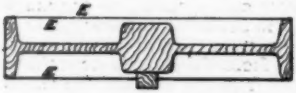


FIG. 4.

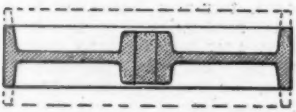


FIG. 1.

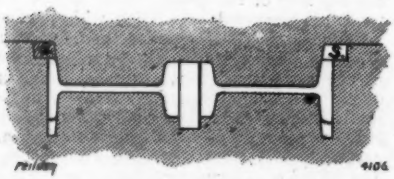


FIG. 3.

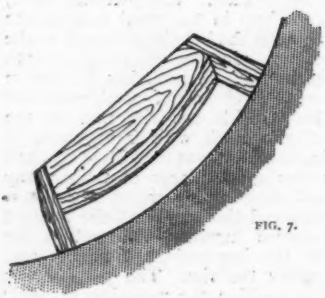
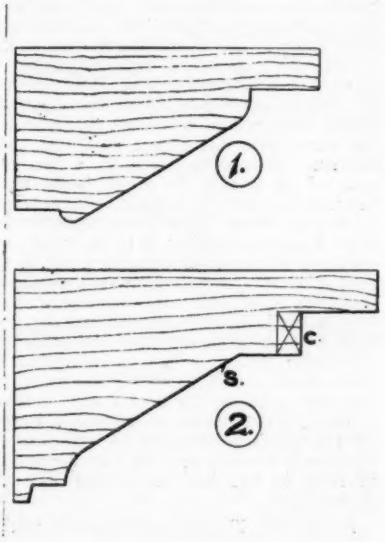


FIG. 7.

GREEN SAND WRINKLES.

a series of cores formed in a box (as Fig. 6) for the bottom part of the mould. In either case the ramming-up is proceeded with until a level is reached which somewhat represents the surface to be formed; then the strickle is swept round, and forms the plane coinciding with the edge of the rim. This surface is prepared with parting sound, and the projecting portion of rim, which forms a recess in the top box, is then filled up, the bottom half of the mould, on withdrawal of the pattern, receiving the dry sand cores, which are sprigged in position. Circular patterns, such as pistons, discs, or large face-plates, can be reduced in the mould by the use of a "stopping-off" piece, as Fig. 7, employed as follows. The pattern is first prepared in the shop, with the necessary alterations marked thereon, and is then sent to the foundry in the ordinary way, with the full complement of core-boxes, etc., and the additional "stopping-off" piece, the part to be "stopped off" being indicated by a number of diagonal chalk marks, these marks being an understood sign throughout pattern-shop and foundry that this particular portion so marked is to be excluded from the mould. In the foundry the usual operations are gone through, and a complete mould of the pattern is made, the portion to be "stopped off" being noted by the moulder, in order that he may make any arrangement or modification in mould or cores to meet the exigencies of the case. This, however, is still made more apparent by the transfer of the chalk marks to the face or other parts of the mould. The "stopping-off" piece (Fig. 7) for a circular pattern consists of a segment of timber, coinciding with the depth of the pattern, and of the *same radius* as the

required casting. Two strips of timber, equal in thickness to half the amount of reduction, are fastened on the ends, as shown, and these serve to set the segment the correct distance from the inside of the mould to the face. On the withdrawal of the pattern, the segment is inserted and held fast against the side while the intervening space between the strips is filled in with facing-sand, gently rammed, so as to secure a surface equal to the original. This operation is continued round the circumference, the final move leaving the impression of the two strips; these are filled up, the mould being then blackened and smoothed up in the ordinary way. The converse operation, viz. the enlargement of a circular pattern, is effected by means of a segment representing *half* the thickness of the required diametral increase. This is rammed up simultaneously with the pattern, being moved round the periphery until the circle is completed. A further illustration of the application of strickle and core-box to green-sand work, is that of a special wheel-moulding job, as follows: A particular arrangement of shafting necessitated the employment of a dished wheel, as shown in section at Fig. 1. As there was no existing pattern which could be prepared to meet the case, the following method was adopted for making the casting in green sand. A pit, some few inches larger and deeper than the wheel, was dug in the floor of the moulding shop, and a 2-in. spindle was then fixed in the centre. Two strickle-boards 1 and 2 were made, No. 1 being first used, screwed to a strap free to revolve round the spindle, and kept to a fixed height by a collar on the underside. A recess thus formed corresponded with the contour of the inside of the wheel. The board was then removed, and this portion of the mould freely sprinkled



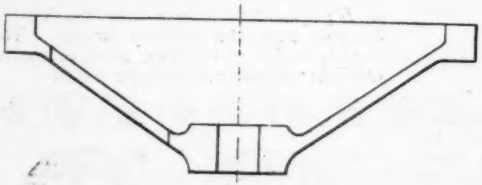


FIG. 1.

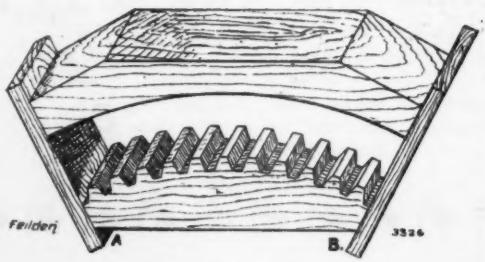


FIG. 2.

with parting sand. A top-part moulding box about 1 ft. larger than the wheel was placed in position over the spindle and located with stakes driven in the floor and binding against the edges of the box lugs. The box was then removed for convenience of covering the strickled-out portion with facing sand to about the depth of 1 in., the top part being then returned to position and the remainder of the recess filled in and rammed with black sand, supported with a plentiful supply of gaggers. The ramming up being completed, the top part was lifted away, and 2 ins. of sand cut from the bottom surface. A layer of facing sand was sieved over and well packed on the surface; then board No. 2, attached to spindle and swept round, forming bottom of mould and contour of casting on side *B*. A sprig inserted at *S*, and filed to a point, described a line to

which the cores forming the openings between the arms were set, a segment of timber being used as a distance gauge between each core, which was kept in position by a couple of long sprigs through each. The mould was then blackened, sleeked, and skin-dried with hot plates, after which the segment cores forming the teeth were set round the seating *C* made by No. 2 board. The mould was then closed, weighted, and run through a "gate" set over the boss with a couple of "risers" on the rim. The wheel, which contained an odd number of teeth, was to be machine-cut. The object of forming the teeth roughly was to relieve the strain, which would have been produced had the wheel been left with a solid rim. The segment cores were made in a box constructed as Fig. 2, the joints being made between the teeth, and the division arranged by the following rule: Each segment contains a certain number of teeth, which is a measure of the whole number; but in the case of wheels containing an odd number of teeth, as 73, 39, etc., any number of cores may be used, and the complement made up with a short piece of core containing the remainder of the teeth. In order that the cores shall joint properly at the ends, the included angle of the box *A* to *B* is found by dividing the number of degrees in a circle by the quotient obtained by dividing the number of teeth in the wheel by the number of teeth in the box, as in the following example:—

A wheel, 73-*T*, core box contains 11 teeth—

$$\frac{73}{11}=6\tfrac{7}{11}.$$

Then $\frac{360}{6\frac{7}{11}}=54{\cdot}3^{\circ}=$ included angle of box.

The operation may be used for other forms of wheels, but it must be pointed out that this particular method is only applicable to green-sand moulding, a similar job in loam necessitating a different arrangement of strickles. A correct form of tooth may be inserted in place of cores by using a block on which a couple of teeth are fixed of the required shape and pitch. The block is attached to a strickle, which revolves round a spindle set in the centre of the mould, an improvised dividing arrangement being made with a change wheel having the required number of teeth, the spindle diameter, equal to the bore, keeping its concentric; whilst a finger on the strickle is moved into a space of the change wheel as the teeth on the periphery are rammed up.

(Award.) FOREMAN PATTERN-MAKER.

A Cooling Lubricant.

The following parts by weight will be found effective in the case of hot bearings, particularly those of high-speed engines, where it is not always convenient to let the bearing cool down in the ordinary way:—1 of white lead; 2 of black antimony; 2 of soft soap; 4 of best tallow. H. P.

Cotter Linings.

Many of the fitters and erecters engaged on engine work know the difficulty of making a liner for a round-edged cotter, such as is used in connecting rods, etc. This is a simple way of making one. Get a piece of wrought iron or steel tube, with a bore equal to the thickness of the cotter, and drive through it a piece of round iron. Cut the tube lengthwise down the centre with hammer and chisel; this gives two pieces as section marked *A*. Now place the half to be used in the vice, and file edges square with the internal diameter, as at *B*; you then have a liner much more accurate than the ordinary forging. The outside radius of the liner must, of course, coincide with the radius of the cotter.

COTTER.

COTTER LININGS.

WORKSHOP QUERIES.

WILL some of our readers kindly answer the following?

Cutting Chasers.

What is considered the best method of cutting the chasers for adjustable screwing dies?

Tracing Tools.

Is there anything better and simpler than the check system for tracing tools given out from the tool store? H. H.

Tube Drawing.

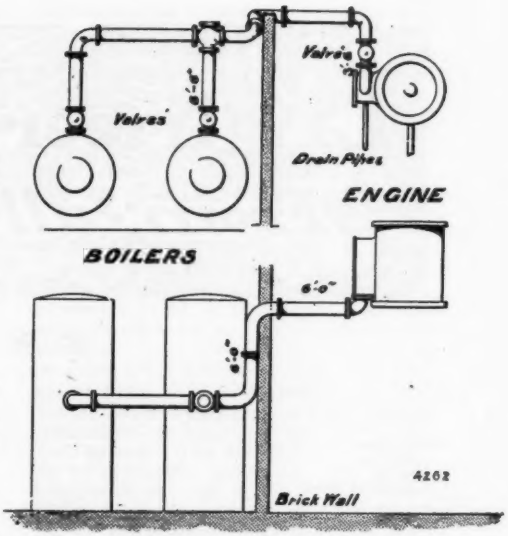
I have an aluminium tube 12 ins. long, ½ in. diameter, ·05 in. thick. How can I reduce it to a gradual taper of, say, ¼ in. at the other end, keeping it a uniform thickness throughout? J. B.

Circumference of Boiler Shell.

How must I ascertain the length of plate for a given diameter? Also is it necessary to bevel the plate at the ends to form a good butt joint? If extra allowance is made for this purpose, does it vary with the thickness of plate? B. M.

Water in Cylinder.

We have an horizontal engine of the ordinary slide valve type, 4 ft. stroke, making 35 revolutions per minute with a pressure of 50 lbs. The cylinder and valve chest are supplied with four 1½-in. drain-cocks, but in spite of these the water in the valve-chest and cylinder causes us much trouble and many leaky joints. How can the water be got rid of? The sketch explains the arrangement of boilers and engine. S. F.



WATER IN CYLINDER.

AS a further inducement to our Artizan readers, and an additional subject of interest, we have decided to assign one page per month to questions bearing on the Workshop and Practice therein.

A query, if deemed suitable, will be inserted and paid for, together with what is considered by the Editor to be the best reply to the same. The decision of the Editor to be final.

The questions and replies should be written on one side of the paper only and should arrive not later than the *second* week in the month for insertion in the following month's issue.

Engineering Notes From all Sources

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The New Graving Dock, Southampton.

A VERY interesting visit was made by the members and the associates of the Society of Engineers on Wednesday, July 16th, to the graving dock now being constructed for the London and South-Western Railway Company at Southampton. The dock, which is being constructed to the designs of Mr. W. R. Galbraith, M.Inst.C.E., will be approached by vessels directly from the estuary of the River Test, which forms one boundary of the dock estate. The river channel is being deepened by dredging to form an ample approach to it. The dock itself will be 860 ft. long (clear inside gates), with provision for extension if necessary ; 90 ft. wide at entrance, with the same bottom width inside ; and 125 ft. wide at cope level. The whole depth from cope to floor will be 43 ft., giving a depth of water over the keel blocks of from 29 ft. 6 ins. neap tides to 33 ft. spring tides at high water. It is built almost entirely of Portland cement concrete, the floor, altars, and walls being faced with this material. The bulk of it is made in the proportion of 8 to 1, the facing to walls and floor, together with the culvert linings, being somewhat stronger, generally 4 to 1. A skin of 4 to 1 concrete is also laid on the underside of the floor, and carried up the back of the walls, so as to prevent any water which may accumulate there from soaking through the more porous concrete into the dock. This 4 to 1 concrete is made with special care, the large stones in the gravel being reduced in a crusher. A mass of 5 to 1 concrete is built in at the skew-back, where the walls and floor meet, to resist the heavy crushing stress at that point. The altars, seven in number, are all grouped near the top. They are 2 ft. 6 ins. wide and only 2 ft. 9 ins. high, and thus very safe and convenient to work on. Access to the floor is given by eight flights of steps, and four slides for timbers are provided. The entrance gates, which will have a span of 90 ft. and a rise of 16 ft. 9 ins., will be of steel, and will be worked by direct-acting hydraulic rams. The hollow quoins and cill quoins will be of granite from the Shap Quarries in Westmoreland. The steps and timber slides will also be faced with this stone. For emptying the dock the water will fall into large pits near the entrance. From these three large culverts will lead it to the pump wells, placed at some little distance behind the eastern wall, and at a depth of 10 ft. below the dock floor. Over these the pump-house will be built, and will contain two 48-in. centrifugal pumps, capable of emptying the 85,000 tons of water in the dock in a little over two hours. Space will be provided for a third pump in case the dock should be lengthened. The boiler-house will be built alongside the pump-house. The site of the dock originally formed part of the extensive mudlands on the River Test shore, which were covered by every high tide. To reclaim the site a bank was tipped round it with chalk taken from the Railway Company's cutting at Micheldever. While tipping this bank a dredger was at work within removing the top mud, which was very soft and foul. The sea-face of the reclining bank was pitched with stone to preserve it from storms, and covered with clay to render it water-tight. The latter process was a very troublesome one, owing to the difficulty of finding suitable clay. A supporting toe of 3-in. sheet piling was provided in places where necessary. As soon as the bank was sufficiently sealed to keep out the tidal water the enclosure was dried out with a 9-in. centrifugal pump and engine, erected just inside the bank. Meanwhile a 1 in 12 incline road, with a winding

engine, had been built at the bow end of the dock, and as soon as the site was dried excavation by hand gangs, by steam crane, and by steam navvy was commenced, the earth wagons being hauled up the incline, and emptied on to other mudlands on the dock estate. The surface was thus lowered to a depth of from 26 ft. to 30 ft. below cope, at which level it was decided that timber trenches should be commenced, in which the dock walls should be built. At the entrance end the chalk enclosing bank approaches very near the dock, and protection was given to it by driving a complete belt or dam of 12-in. sheet piling across the entrance, which in its turn is supported by raking struts. Inside this again a cross trench was sunk, so as to build the first 20 ft. of dock floor, which now forms a massive toe for the timbering. The arrangement of this timbering is worthy of notice. The wall trenches are now being sunk and timbered in a substantial manner, and directly a length is sunk to its full depth the concrete wall is started inside it. When these walls are completed the dumpling between them will be excavated in a similar fashion, and the concrete floor built in length by length. The excavation for the pump wells, etc., is being similarly dealt with, the trench being heavily piled to avoid all risk of dislocation. Any water which finds its way into the enclosed area is led by pipes and grips to one or other of two pumps, which are provided to keep the works dry.

Separating Oil from Feed-Water.

In a paper recently published in the *Journal of the Association of Engineering Societies*, Mr. J. R. Bibbins describes the steps taken to remove oil from the feed to the boilers of the electric-light station at Detroit. The station in question is a small one, the plant being driven by two condensing engines of 400 h.p. each. At the outset an attempt was made to separate the oil by passing the discharge from the condenser through a coke filter. The filter consisted of a wrought-iron pipe, 14 ins. in diameter inside and 10 ft. high, filled with broken coke. The inlet was at the top of this filter, and the water after purification was drawn off below. This arrangement proved ineffective, partly because it was overlooked ; and an examination was then undertaken to ascertain whether some other method was not available for separating into its constituents the emulsion of oil and steam. It was found that, on submitting the mass to heat and pressure, separation was easily effected, as might, perhaps, have been anticipated from the fact that the oil separates out in the boilers. It was not, however, considered feasible in practice to pass the feed through a subsidiary heater before it entered the main boilers, and other means were accordingly sought, and at the same time an attempt was made to discover in what way the oil was carried into the condenser. A sampling pipe put into the 15-in. horizontal main from the engines showed that the steam in the upper part of this pipe was quite free of oil, but that the lower part of the pipe, which formed a pocket, owing to both the engines and the condenser being at a higher level, was filled to a depth of $3\frac{1}{2}$ ins. with an emulsion of oil and water. If this was removed by trapping, the steam entering the condenser would be free of oil. The first step, therefore, was to fit such a trap, and the second to separate out the oil from the emulsion discharged by the trap. Attempts to remove the oil by saponification were fruitless, as the oil contained no animal or vegetable greases. It was, however, discovered that freshly-prepared milk of lime coagulated the emulsion most successfully, and that on filtering off the precipitate perfectly clear and oil-free water was obtained. A plant based on this principle has accordingly been designed. All the trap discharges are collected into a well, and pumped thence into a settling tank, and to this freshly-prepared milk of lime is then added. The contents of the tank are then agitated for about four minutes by means of compressed air, after which the mixture is left to settle for ten to fifteen minutes, and the clarified water drawn off through a filter.

Sea-Water and Portland Cement.

With a view to further elucidating the effect of sea-water on Portland cement concrete, says *Engineering*, a series of experiments on a very large scale are about to be undertaken by the Prussian Government, in conjunction with a number of prominent cement manufacturers. A number of large concrete blocks, made with cements of different compositions, are to be sunk in the sea off the coast of Sylt Island, and will be examined periodically. At the same time, briquettes of the mortar used, and blocks of the concrete will be immersed in tanks on the land. Some of these tanks will contain fresh and the others salt water. Both tensile and compressive tests of these briquettes and blocks will be made from time to time. The mortars used will be compounded so as to determine whether an addition of slag or strass improves the resistance of a cement to sea-water. The experiments are expected to extend over a period of thirty years.

REVIEWS.

Æther and Matter. By J. Larmor. (Cambridge University Press, 1900; price 10s. nett; xxvii and 365 pages.)

This work is an enlargement of an Adams Prize essay in the University of Cambridge, the subject set being "The Aberration of Light." Until quite recently, the phenomena in which the motion of matter relative to ether is a factor were purely optical, the astronomical aberration of light being the most important one, so that the subject proposed for the essay led naturally to the consideration of ether and matter, and their relations to each other.

The author had for some years previously been developing, in a series of memoirs which appeared in the Philosophical Transactions of the Royal Society, a systematic construction of general electric theory on the basis of intrinsic atomic charges. In the course of these investigations he was led to the conclusion that the only possible means of arriving at a dynamical explanation of the electrification of the ether, in accordance with known phenomena, was on the theory of such intrinsic atomic charges, or electrons, in an ether of the type determined in 1839 by MacCullagh, by purely abstract dynamical reasoning from known optical phenomena, and the equations obtained by him are identical with those required by Maxwell's electro-optical theory. MacCullagh shewed that the elasticity must be wholly rotational, so that the ether would be perfectly fluid for all motions of irrotational type, but would resist elastically, by a reacting torque, any differential rotations of the elements of volume, somewhat after the manner that a spinning fly-wheel resists any angular deflection of its axis. Solid bodies would be able to move freely through such an ether, just as if it were a perfect fluid, and vortex rings could permanently exist in it.

Lord Kelvin's vortex-ring theory of matter does not in itself take account of electric phenomena as does the theory here set forth, that material molecules are built up of systems of electrons in stable orbital motion. Two kinds of electrons, positive and negative, must be postulated, and the charges on them are all equal in amount. These electrons are considered to be essentially singularities in the ether, so that the only way in which one electron can differ from another is chirally—viz., as the right hand differs from the left, or as an object differs from its image in a plane mirror. The orbital motions of a molecule must of course satisfy the conditions of dynamical stability, and they must not give rise to radiation unless disturbed, as otherwise they would not be able to exist permanently. Vortex rings might be imagined which would fulfil these conditions, but as vorticity has not been required, so far as the author's investigations have extended, he sees no present necessity for introducing such a limitation to the general theory. At present, no attempt has been made to determine the possible types of molecules which would fulfil the above conditions. It would form a most interesting, but by no means easy subject for mathematical research. The question of whether or not material molecules, if built up of electrons, as the author shews strong reasons for believing to be the case, are subject to the condition of vorticity, is one which appears to us of the greatest interest and importance, although outside the scope of Professor Larmor's present investigation. If material molecules are built up of linked vortices, transmutation becomes impossible, while without such a restriction on the electron molecules it would appear to be theoretically possible, though the conditions under which it might take place could hardly be discussed until the possible types of molecular electron systems have been investigated.

The author points out that there is an essential distinction between thoroughgoing constitutive theories of the ether, such as the vortex-atom theory and the one propounded by himself, on the one hand, and the usual theories of radiation, which ascribe to the ether an extremely small density in comparison with that of matter. In the former the ether is regarded as fundamental, and its properties must be such as to be consistent with the whole range of physical phenomena; while in the latter we have an independent system of dynamics, of matter treated as fundamental, and the properties of the ether are then determined so as to interfere therewith as little as possible. Under these conditions the ether is practically regarded as a species of matter. The difficulties of such theories of the ether become great as soon as we attempt to apply them to the modern theory that the energy of a magnetic field is distributed in the surrounding region of free space, and is constituted of etherial kinetic energy. If a very small inertia be assumed, there must be, either translational velocities of the ether of quite impossible magnitudes, or else a cellular structure in which the energy exists in some way as energy of gyrostatic rotation, which transfers the difficulty to the conception of a mechanism by which the vibrations of simply material atoms can transfer energy into a medium so differently constituted. When the ether is taken as fundamental, this difficulty no longer arises, the whole energy of the atomic vibrations belonging to the ether, because the atoms themselves form part of it.

Taking the view set forth in this volume, that the ether is fundamental, mechanical models and analogies cannot be expected to carry us very far, as we have no direct experience of the properties of ether, and therefore have to fall back on ordinary matter out of which to build up our mechanical models. That is to say, in order to arrive at a conception of the actions going on in the fundamental material, in which matter is a more or less complex structure, we must make our models of these complex structures. Such models cannot therefore be expected to assist us greatly in arriving at the properties of the simpler ether, for which we have to rely on abstract dynamical reasoning, based upon observed phenomena. When, however, the properties have been determined in this manner, it is a great assistance in co-ordinating the different properties to translate the abstract analytical concepts into even such imperfect models as can be built up of ordinary matter. A model

of an ether of the kind considered by Professor Larmor may be imagined on the lines of Lord Kelvin's gyrostatic vibratory ether.

This ether is a perfect fluid, having rotational elasticity, so that in the first place we have to construct a model of a perfect fluid, which is a type of medium unknown in the material world. Its characteristics are continuity of motion and absence of viscosity. In an ordinary fluid, continuity of motion is secured by diffusion of momentum by the moving molecules, which is itself viscosity; so that it is only in the case of such motions as those of vibration and slight undulation, when the other finite effects of viscosity are negligible, that ordinary fluids can be treated as perfect.

An aggregation of frictionless solid spheres will form a possible, though crude, representation of a perfect fluid; and in order to maintain continuity of motion without viscosity, each sphere may be supposed to be studded over symmetrically with a small number of frictionless spikes of length considerably less than the radius of the spheres. We have now to impart to each of these spheres the elastic property of resisting absolute rotation. Imagine a gyrostat, consisting of a spinning fly-wheel, with its axis pivoted as a diameter within a ring, while the diameter of the latter, which is perpendicular to the axis of the fly-wheel, is itself pivoted on the spheres.

Let three such rings, in mutually perpendicular planes, be mounted on each of the spheres, then if the gyrostats are all exactly similar, both in size and spin, the spheres will resist absolute rotation with isotropic elasticity, so long as the total displacements of the areas of the fly-wheels are small.

If the angular momentum of each gyrostat is great enough, it will require a proportionally long time for a given torque to produce an assigned small angular displacement, and by taking the momentum great enough, this time can be prolonged as much as we please. Now, the author shows, in the course of the work, that the motion of the rotationally elastic ether is everywhere irrotational, except where electric force exists. This gives rise to rotation proportional to its intensity. Now, a high co-efficient of inertia, and, therefore, a very high elasticity, is required, on account of the known speed of radiation; from which it follows that the very strongest electric forces produce only very slight rotational displacements of the medium. Therefore, the model described above, although it cannot strictly represent the action of a field of steady electric force lasting for ever, can theoretically represent such a field lasting without sensible decay for any length of time that may be assigned.

To illustrate the formation of electrons in a rotational ether, imagine two points at which it is desired to develope complementary electrons to be connected by means of a flexible shaft or wire, of infinite torsional rigidity, and in continuous connection with the surrounding ether, the ends of the wire being fixed at the two points. When any cross-section of this wire is rotated round its axis by an impressed torque, the rotation is transmitted all along the wire, and thence to the ether alongside it, developing complementary electrons at the fixed points. When the torque is withdrawn, the rotation undoes itself, and the terminal electrons disappear. If, before withdrawing the torque, the wire is replaced by studded gyrostatic spheres, that is, by ether, with the exception of small nuclei at the two fixed points, the effort of release in the surrounding medium will slightly rotate the spheres in the channel formerly occupied by the flexible shaft, until they attain a state of equilibrium, in which the rotational elasticity of the new part of the medium formed by their aggregate provides a balancing torque, and the conditions round the two nuclei will finally be symmetrical. Two permanent conjugate electrons will then have been created, each of which can be moved freely through the medium, somewhat in the same way that a knot would slip along a frictionless string, but they will both persist until they are destroyed by an extraneous process the reverse of that by which they are formed, for such a model electron will persist for any finite assignable time if the distribution of gyrostatic momentum in the medium is sufficiently intense. The constitution of the model of course excludes, in this respect also, absolute permanence. A very interesting point arises in connection with the atomic nuclei referred to above.

MacCullagh's equations for the free ether are linear equations, which they must necessarily be if all kinds of radiations are to travel with the same speed in the celestial spaces. It has been suggested that this is only true as a first approximation, just as the linear scheme of equations of the theory of the propagation of sound covers the whole of the phenomena of acoustics, although in arriving at those equations from the dynamics of gaseous fluids, all terms involving the square of the ratio of the velocity of the actual aërial disturbance to the velocity of its propagation are neglected, for the reason that their consequences are outside the limits of observation. If the equations are rigorously linear, the principle of dynamical similarity leads to the result that the properties of molecules built up of electrons which are merely point singularities in the ether, without nuclei of finite size, would be independent of the scale on which they were built, which would not be in accordance with the definiteness of scale of the molecules of matter as known to us.

The size of a molecule would be rendered determinate, independently of finite nuclei, if there were residual non-linear terms in the ethereal equations, which became sensible at intermolecular distance. If, however, such terms existed, a train of radiation from a distant star would change its form as it advanced across space — viz. there would be optical dispersion in the free ether. The possible amount of this would be extremely minute, since celestial bodies on emerging from eclipse or occultation show no changes of colour.

It has been suggested that some such minute effect might serve for the explanation of gravitation, the smallness of the amount required for this purpose being shown by a comparison of the electric force between two electrons, with their gravitational attraction.

Against this the author argues that unless the effects of such terms of higher order, in the equation of etherial activity, increased enormously in importance at molecular distances relatively to the linear terms, the proposition that the interactions of molecules are mainly of electric quality would remain valid; and he points out that such increase of importance does not seem likely as regards the mechanism of gravitation, since gravity and electric force both obey the same law of the inverse square of the distance, a law which, in fact, belongs of mathematical necessity to the steady permanent interactions between molecular nuclei of elastic or motional disturbance in an extended medium, when they are of the type of simple poles. He points out, moreover, what appears a still more fatal objection to the possibility of explaining gravitation in this way, that any action thus accounted for would have relations with radiation, including a velocity of transmission of the same order as that of light, whereas it is known that the speed of transmission of gravitation, if finite at all, enormously transcends that of light.

These considerations tend strongly to the conclusion that gravitation cannot be expected to be involved to any appreciable extent in the scheme set forth to explain the phenomena of electrodynamics, in which terms optics are, of course, included. He expresses the opinion that the only obvious way of representing it seems to be the introduction of the time-relation inherent in pulsating nuclei, and he points out that the existence of a configuration of minimum energy in the molecule necessarily implies some kind of finite structure in the nuclei.

The electric nuclei, however, although they may be purely ethereal (it hardly seems possible to conceive atomic inertia, except as far as it is derived from the ether) are local, and thus not pertinent to general electrical theory.

If space allowed, I should like to consider many other questions of interest, which are treated in the most able manner by the author, but I trust that enough has been given to lead many of my readers to study the work for themselves. They cannot fail to find it a rich intellectual treat.

The mathematical treatment adopted is based upon the principle of least action, and the author, in one of the appendices, takes occasion to defend it against the objections which have been urged against its being taken as a fundamental principle on which a general theory of mechanics may be built up.

The most formidable of these is that taken by Hertz—viz., that it does not apply to all natural motions, for it requires that, if fixed connections exist between the chosen co-ordinates of a system, these connections must be expressible mathematically by finite equations between the co-ordinates, which is not always the case in natural motions. For example, when bodies of three dimensions roll upon each other without slipping, there must necessarily be at least one non-integrable differential equation connecting the co-ordinates.

Larmor attempts to meet this objection by asserting that "it may be urged that the motion of rolling is foreign to molecular dynamics, on which the laws of mechanical dynamics must be ultimately based." It might on the other hand be urged that, considering how very little we really know about the nature of molecular mechanism, we have no right to categorically exclude even this notion of rolling; and even if Larmor's contention be admitted, it does not answer Hertz's objection. To do this we should have to maintain that no motions can occur in molecular dynamics of a kind which would lead to non-integrable differential equations between the co-ordinates. We can see no grounds for making such an assertion as this; indeed, in one case at least, viz., Maxwell's law of the partition of energy in a gas, Hamilton's principle appears to lead to conclusions which are in direct conflict with observed facts. It appears to us that the only safe ground to take up is, that Hamilton's principle has proved to be a trustworthy guide over so wide a range of natural phenomena, that if motions of the kind to which it does not apply do occur in nature, they can only do so very rarely, and that the balance of probability is therefore in any special case largely in favour of its employment being legitimate.

Another objection which has been raised against the principle of least action is that it cannot be fundamental, inasmuch as it determines the present course of a system by a reference to its future as well as to its past. Larmor's reply to this is that "the objection will be removed if we bear in mind that the complete system is of very complex molecular constitution, and that the principle of action is really only an algorithm, constructed so as to enable us to abstract the molecular details while retaining all that relates to the matter in bulk."

An objection of a somewhat similar character might be raised against other modern analytical methods, such as that of the Vector Potential, which is also employed by the author, inasmuch as by the procedure of integration through all space they make the state of any system at any given time depend on the simultaneously existing conditions throughout the universe.

Our reply to both objections would be, that in using such general methods of dynamical reasoning, we contemplate whatever system may be under consideration as a part of the sum total of things, or the universe, which we can only think of as being extended both in space and time. Of this sum total of things we endeavour to abstract so much as will determine the system to the extent required, if possible, and if not, as far as we are able, and ignore the remainder. From the philosophical point of view, the space and time relations to our system of the utilised portion of the sum total are a matter of indifference.

Professor Larmor's reply appears to be to the same effect, but in so condensed a form as to render it at first sight somewhat difficult to grasp. We may also point out that the determination of the present state of a system by its future as well as its past is paralleled in every-day life whenever our actions are determined by future events.

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